Virginia City Hybrid Energy Center
Response to Data Request
Bruce Buckheit, Member, Virginia Air Pollution Control Board

Question (Page No. 22 and 25)

EFFICIENCY IMPACT OF PROPOSED FUEL MIX

In order to evaluate whether examination of this issue might be significant, I performed what I would style "an order of magnitude" calculation based on published data. The "run of mine coal" has an ash content of greater than 40% (nominally 44%). In addition, Dominion proposes to use substantial amounts of waste coal and gob. Dominion's application discloses that it intends to use 3,525,000 tons/yr of "coal." Total fly and bed ash production is given at 2,600,000 tons/yr – of which 350,000 tons/ yr. can be assumed to be limestone. The ash content for the mix then would appear to be 63.8%. Ash content is for clean coal is assumed to be in the range of 7 – 10%. Using the specific heat for "soil" (0.25 btu/lb ^{o}F)[1] and assuming that in order to assure complete combustion of coal, the ash must be brought from "room temperature" to the operating temperature of the boiler (nom 1500 ^{o}F) the energy required is calculated.

At 10% ash content annual ash generation would be 352,500 tons; at 7% it would be 246,750 tons. Thus if we assume 7% ash content for clean coal, the difference in the amount of ash that would have to be heated to 1500 ^{o}F is (2,250,000-246,750) = 2,003,250 tons/yr

$(2.0 \times 10^{6}$ tpy) x $(2.0 \times 10^{3}$ lb/ton) x (0.25 btu/ lb^{o}F) x 1500 ^{o}F = 1.50×10^{12} btu or 1.50×10^{6} mmbtu

In its application Dominion apparently asserted that the heat rate for the plant is 10,800 btu/kwhr; while at a Board meeting the Dominion representative stated that the heat rate was slightly less than 10,000 btu/kwhr[2]. This needs to be clarified, in the long term, for purposes of this order of magnitude calculation I use 10,400 btu/kwhr. I assume a nominal 90% unit availability.[3]

Total heat:

(10,400 btu/kw/hr) x $(1 \times 10^{3}$ kw/MW) x (668 MW) x (.9) x (8760 hr) = 5.47×10^{13} mmbtu or 54.7×10^{6} mmbtu.

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[1] http://www.ac.wwu.edu/~vawter/PhysicsNet/Topics/Thermal/HeatCapTable.htm , citing Tipler, Paul A., Physics for Scientists and Engineers, 4th Ed., W.H. Freeman, (1999).

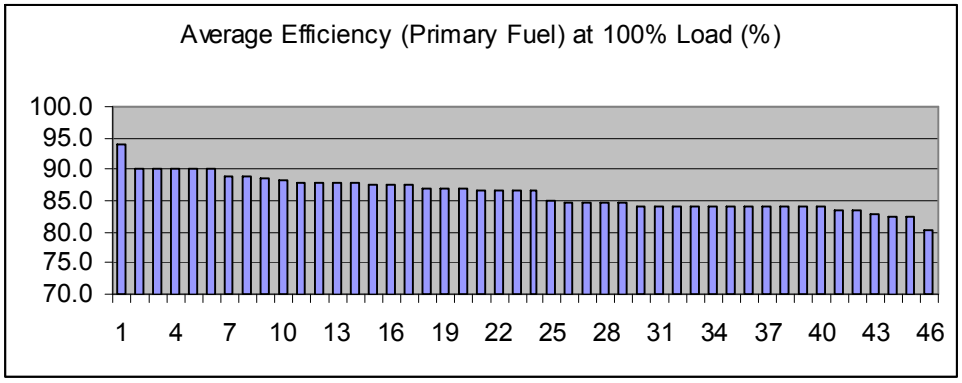
[2] I suspect that this may be due to differences in calculating the heat rate at HHV (higher heating value) versus the figure for LHV (lower heating value).

[3] I have not examined the assumptions underlying Dominion's calculation of coal consumption and ash generation.

$(1.50 \times 10^6 \text{ mmbtu}) / 54.7 \times 10^6 \text{ mmbtu} \times 100 = 2.74\%$

Repeating this calculation assuming 63.8% ash content for Dominion's proposed fuel and 10% ash content for cleaned fuel yields a result of 2.60%.
This calculation suggests that nominally 2.7% of the annual energy consumption of the plant is associated with simply heating the excess ash to 1550 degrees F. While this may appear small to some, according to the literature achieving gains of this magnitude are considered quite significant within the industry. From an environmental perspective the potential significance of this issue may be analogized to the amount of biomass farming that would be required to offset a 3% decrease in efficiency. Based on the Cary Institute calculations incorporated in the questions of Vice-Chair Thomson, it can estimated that a 50 square mile tree farm (slightly more than 10% of the land area of Wise County) would have to be created and maintained to offset even this level of decrease in efficiency.

I recognize that boiler design is a complex matter and that more detailed calculations may be necessary to examine in detail the impact of Dominion's proposed fuels from a design perspective. Please ask Dominion to provide the design boiler efficiency, net plant heat rate and net plant efficiency (1) for the current proposed fuel and (2) assuming nominal values for commercially available Virginia coal. In addition, data concerning efficiency of other CFB's operating on commercial coal in the U.S. is readily available. I have compiled data available from DOE's National Energy Technology Laboratory[4].



[4] See, www.netl.doe.gov/energy-analyses/pubs/database/NETL%20CPPDB%202007%20-%20Public.xls and the user manual http://www.netl.doe.gov/energy-analyses/pubs/database/User%20Manual%20-%20CPPDB%202007%20-%20PUBLIC.pdf . This data base is a very large file. I have created a subset of the most relevant information, see attached. The most efficient units appear to be very small units, with only the Northside Generating station unit (about half the size of the VCHEP units) at or above 90% efficiency. However, even very old CFB units can have relatively high efficiencies when burning quality fuels. The five Barry units were installed in 1959 and 1971 and show boiler efficiencies of 88% and 89% respectively.

Plant Name	Service date	Average Efficiency	Firing Rate (tons/h)
Rumford Cogeneration	12/1/1990	86.7	415
	12/1/1990	86.7	415
Seward[5]	**3/1/2004**	**86.5**	**230**
	3/1/2004	**86.5**	**230**
Red Hills Generating Facility	3/1/2002	82.4	210
	3/1/2002	82.4	210
Twin Oaks Power One	9/1/1990	83.4	121
	10/1/1991	83.4	121
H L Spurlock	4/1/2005	88.4	120
Northside Generating Station	5/1/2002	90.0	96
AES Warrior Run Cogeneration Facility	2/1/2000	88.9	90
	8/1/2001	86.9	89
Colver Power Project	5/1/1995	87.0	84
Marion	5/1/2003	88.7	80
Northampton Generating Company	8/1/1995	85.0	74
R M Heskett	11/1/1963	80.3	68
	2/1/2001	86.9	67
	5/1/1997	87.5	66
Shawnee	12/1/1990	88.0	66
ACE Cogeneration Facility	6/1/1990	33.1	58
Nucla	1/1/1991	88.3	58
AES Hawaii	9/1/1992	87.6	42
	9/1/1992	87.6	42
Cedar Bay Generating LP	1/1/1994	90.0	41
	1/1/1994	90.0	41
	1/1/1994	90.0	41
AES Thames	3/1/1990	87.8	39
	3/1/1990	87.8	39
Archer Daniels Midland Cedar Rapids	10/1/1988	84.0	33
	11/1/1988	84.0	33
	3/1/1989	84.0	33
	10/1/1994	84.0	33

[5] The Seward facility is of special interest since it is described as burning "waste coal" and is approximately the same size as VCHEC. However, the general literature maintains that the Seward unit is a mine mouth unit located on top of an abandoned anthracite mine and does not indicate the coal quality as burned. Moreover, the construction of the Seward unit was accompanied by the retirement of three existing coal fired units and represented a plant betterment project that may not have required a BACT determination. http://www.fluor.com/ias/pow/projects.asp#aes

AES Shady Point	1/1/1991	84.8	28
	1/1/1991	84.8	28
	1/1/1991	84.8	28
	1/1/1991	84.8	28
	12/1/1991	84.0	28
	3/1/1996	84.0	28
Archer Daniels Midland Decatur	2/1/1987	84.0	25
	4/1/1987	84.0	25
	7/1/1987	84.0	25
	7/1/1987	84.0	25
	12/1/1987	84.0	25
Manitowoc	6/1/1990	94.0	11
Green Bay West Mill	6/1/1992	64.0	0
P H Glatfelter	9/1/1989	82.7	0
	4/1/2008	88.0	0
	5/1/2002	90.0	0

Even though they are relatively new units, the AES Cogeneration facility and the Green Bay West Mill CFB's have significantly lower efficiencies than the other units shown. I suspect this may be because of the nature of the fuels they combust. Examining the combustion efficiency of these units and the recently permitted waste coal combustors identified in the Wayland memo may provide useful information.

Response:

Based on the design fuel, the VCHEC guaranteed heat rate is 9973 Btu/kWh (HHV) which is lower than what is indicated in the calculations. This value was determined at LNTP after extensive detailed engineering after submittal of the air permit application in 2006.

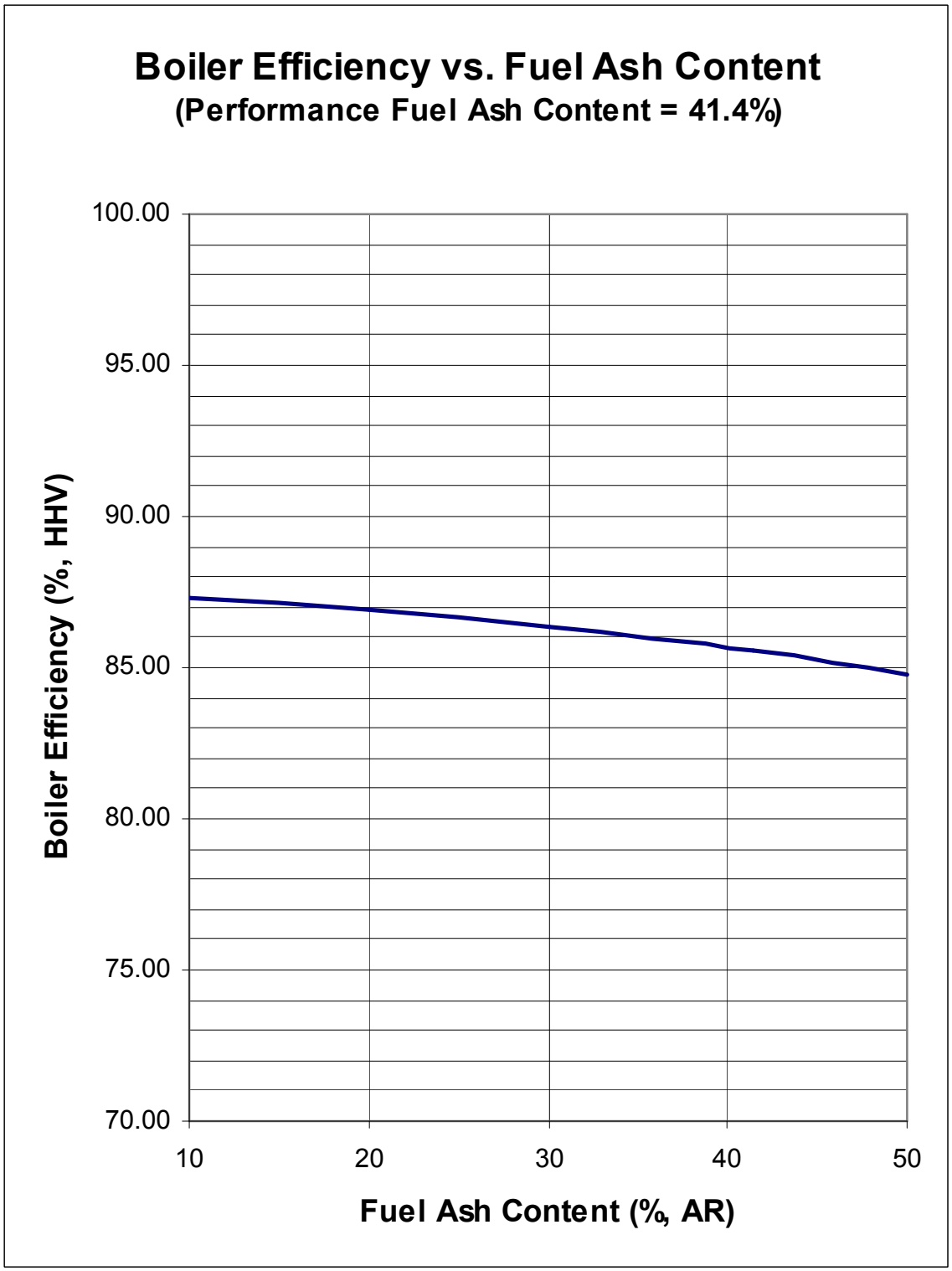
As indicated in an earlier response, the heat from the ash is recovered in the steam cycle by heating condensate going to the boiler. The expected decrease in heat rate is 53 Btu/kWh with an additional output of 2.1 MWs.

Based on the design fuel, the VCHEC boiler efficiency is 85.7 percent. The boiler efficiency does reduce as ash increases in the fuel, however, total plant efficiency and not just boiler efficiency should be considered when evaluating plant emissions or fuel consumption (Attachment 1). The stated boiler efficiency does not include the heat recovery in the steam cycle from the stripper coolers for our project. The overall heat rate does take this into account.

Attachment 2 is a narrative from Foster Wheeler describing the various parameters that effect stated boiler efficiency. Not stated in the narrative is the positive effect that fuel sulfur content has on boiler efficiency as described in an earlier response. Due to these

varying parameters and the fact that there is no commercial standard definition for boiler efficiency between various projects, comparisons between stated efficiencies in a government database is not meaningful.

ATTACHMENT 1



The boiler efficiency does reduce as ash increases in the fuel, however, total plant efficiency and not just boiler efficiency should be considered when evaluating plant emissions or fuel consumption.

ATTACHMENT 2

DOMINION VCHEC PRO ECT

HO DOES THIS BOILER EFFICIENCY COMPARE TO OTHER CFBS:

The boiler efficiency as reported depends upon several factors as listed below:

1. Fuel analysis
2. Ambient conditions (avg ambient temp % relative humidity)
3. Contract agreement on reference temperature (baseline for heat losses)
4. Contract agreement on taking credit for W consumed in boiler boundary
5. Any credit agreed to for the sensible heat loss that is used by transfer to condensate system.
6. Any backend scrubber system that would limit the lowest fluegas temperature that can exit the boiler.

For a given boiler any change in any one of the above parameters will change the reported boiler efficiency. Hence, it is impossible to compare or comment on the reported boiler efficiency for the list of boilers referenced, not knowing all the above data.

EFFECT OF ASH CONTENT ON BOILER EFFICIENCY:

For a given boiler the impact of changing ash content alone, keeping all other input variables at the same level is indicated in the curve 1. The fuel composition for the various ash contents are obtained by converting the performance coal to dry ash free basis and converting back to the same moisture and different ash content. As could be seen, the change in ash content does have an impact on the boiler efficiency but not at a significantly high level.

EFFECT OF AMBIENT CONDITIONS:

For a given boiler the impact of changing the ambient temperature by 10 F would change the boiler efficiency by 0.13%

EFFECT OF CONSUMED ON BOILER EFFICIENCY:

This typically could increase the reported boiler efficiency by 0.8% if considered.

EFFECT OF UTILI IN BOTTOM ASH HEAT IN CONDENSATE SYSTEM:

This typically could increase the reported boiler efficiency by 0.90% for the performance coal, if considered. This benefit drops as the ash content is lowered.

IMPACT OF BAC END SCRUBBER OF BOILER EXIT TEMPERATURE:

The scrubber system adds to the concern of operating close to the acid dew point and would require a higher fluegas temperature exiting the boiler while firing a lower ash fuel by utilizing steam coil air preheater.