Resource and Financial Impact of Clean Line P&E HVDC Delivered Wind Resources for TVA

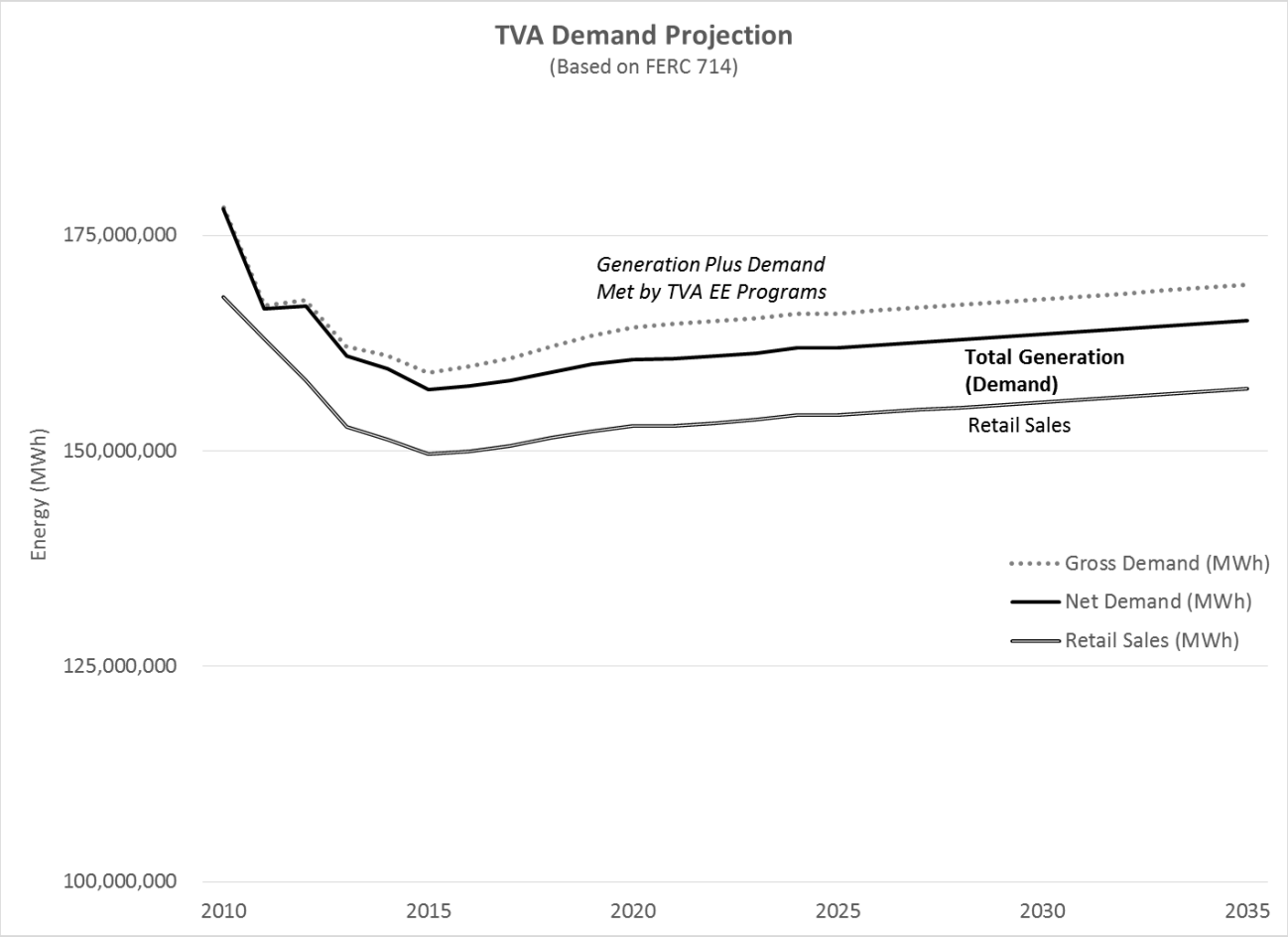
1. What is the potential contribution of HVDC wind to TVA's forecast demand?
   - **HVDC wind could meet 1.4 - 4.1 % of TVA's generation needs in 2023.**
2. How does the (assumed) price for HVDC wind compare to the benefits to the TVA system in terms of fuel costs?
   - **Clean Line wind is less expensive than the cost of fuel at a natural gas power plant.**
3. What are potential savings impacts of Clean Line on TVA rates?
   - **Clean Line will have a small but beneficial impact on TVA rates, saving 0.05 to 0.10 ¢/kWh. Rate savings are small because Clean Line would meet 1-4% of TVA demand.**
4. What are the other potential benefits of HVDC wind to TVA that could be quantified?
   - **Clean Line will include upgrades to TVA's internal transmission system, enhancing system reliability. Clean Line will provide a substantial amount of power during peak hours, also enhancing system reliability during peak hours.**

Energy contribution of Clean Line to TVA

HVDC wind could meet 1.4 - 4.1 % of TVA's generation needs in 2023

TVA 10-year demand projection is nearly flat

TVA's demand and retail sales are unlikely to return to pre-recession levels in the foreseeable future.

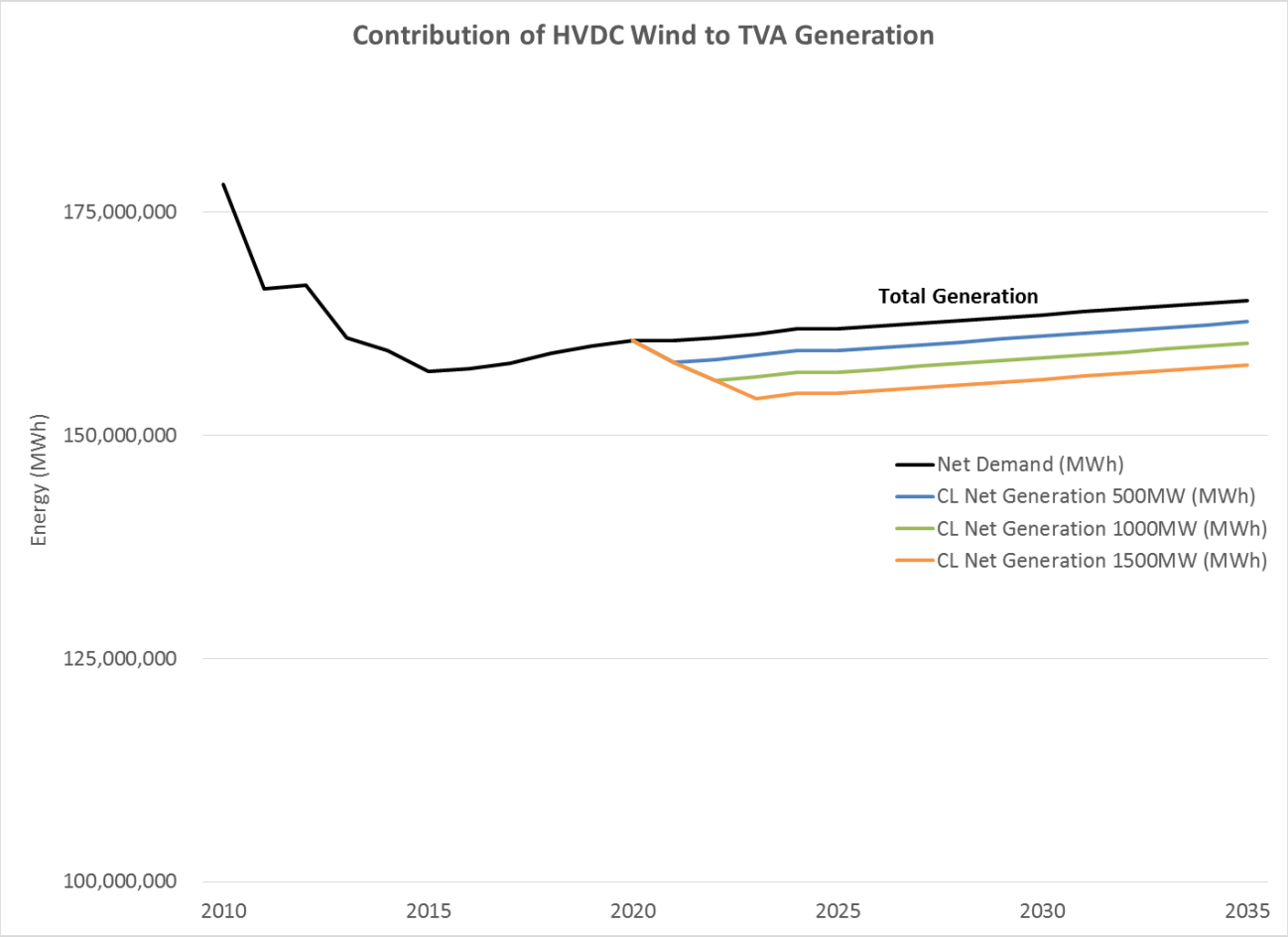


Clean Line wind potential relative to TVA demand

Clean Line wind could meet 1.4 - 4.1 % of TVA's generation needs in 2023.

Assumptions:

- 55% capacity factor
- Delivery of 500 MW in 2021
- Alternatives with additional 500 MW delivered in 2022 and 2023



Price of Clean Line wind vs TVA fuel costs

Clean Line wind is less expensive than the cost of fuel at a natural gas power plant, based on Energy Information Administration fuel cost forecast.

Costs and savings associated with Clean Line wind PPAs

- For initial case, assume only costs are those associated with a wind resource PPA (including transmission)
- For initial case, assume only savings are those associated with natural gas fuel costs at TVA's natural gas power plants (excluding other costs to run the plants)
- Natural gas is the fuel most likely to be affected by additional wind resources, unless coal capacity is retired (addressed later)

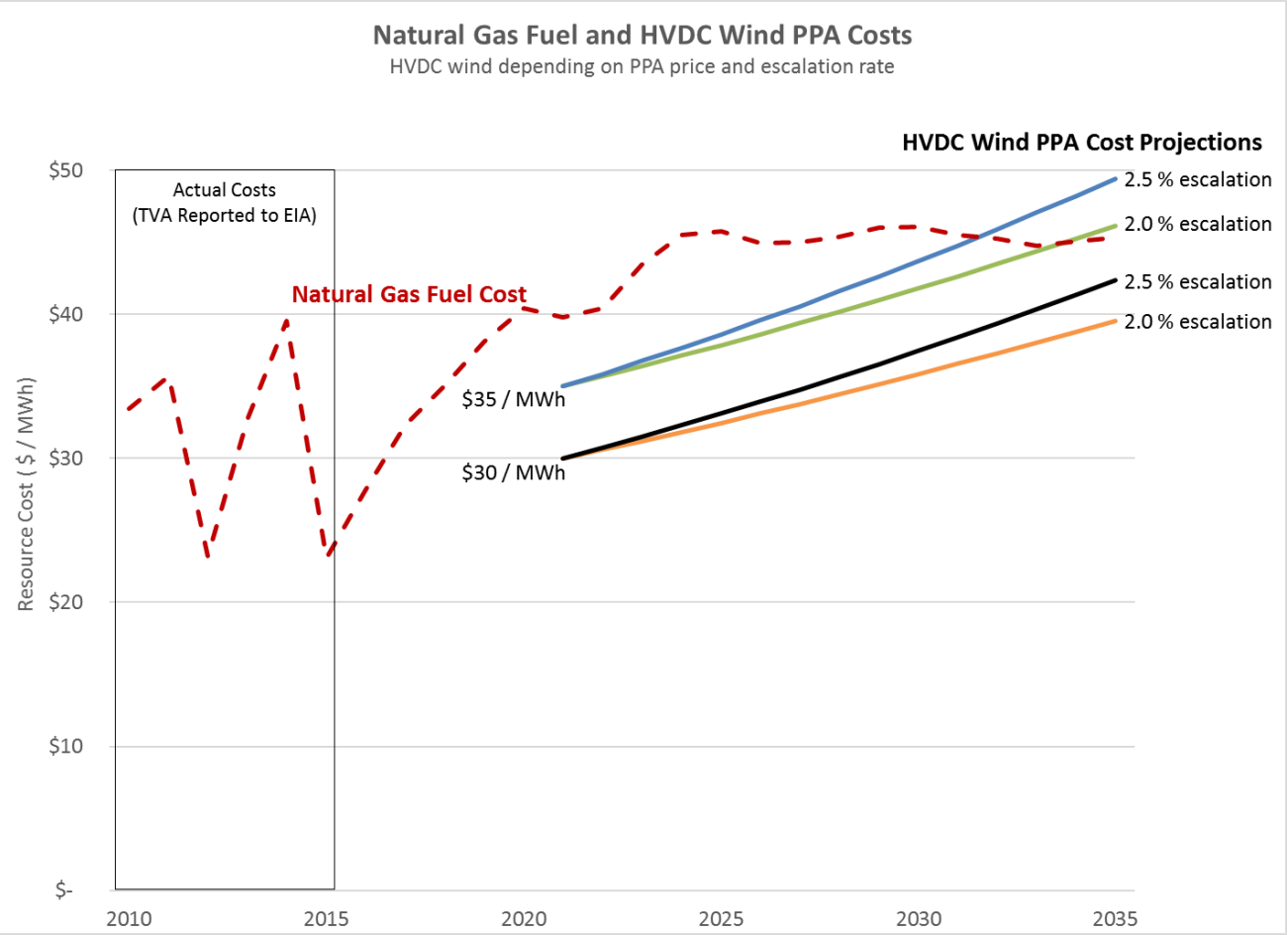
Cost assumptions

	Low	High
Initial Wind PPA Cost	$ 30 / MWh	$ 35 / MWh
PPA Escalation Rate	2.0 %	2.5 %
PPA Term	20 years	25 years
Average Natural Gas Fuel Cost to TVA, 2021	$39.83 / MWh	$39.83 / MWh
Natural Gas Cost Escalation Rate, 2016-35	2.6 %	2.6 %

Assumptions are based on publicly available information from Clean Line Energy Partners, Lawrence Berkeley National Laboratories, Energy Information Administration, and other sources.

Clean Line wind PPA costs should be lower than natural gas prices

Based on the US Energy Information Administration's natural gas fuel cost forecast for the east south central region, TVA's fuel cost for natural gas generation is projected. TVA's fuel cost is based on continued operation of its existing and planned fleet using historic heat rates and capacity factors.

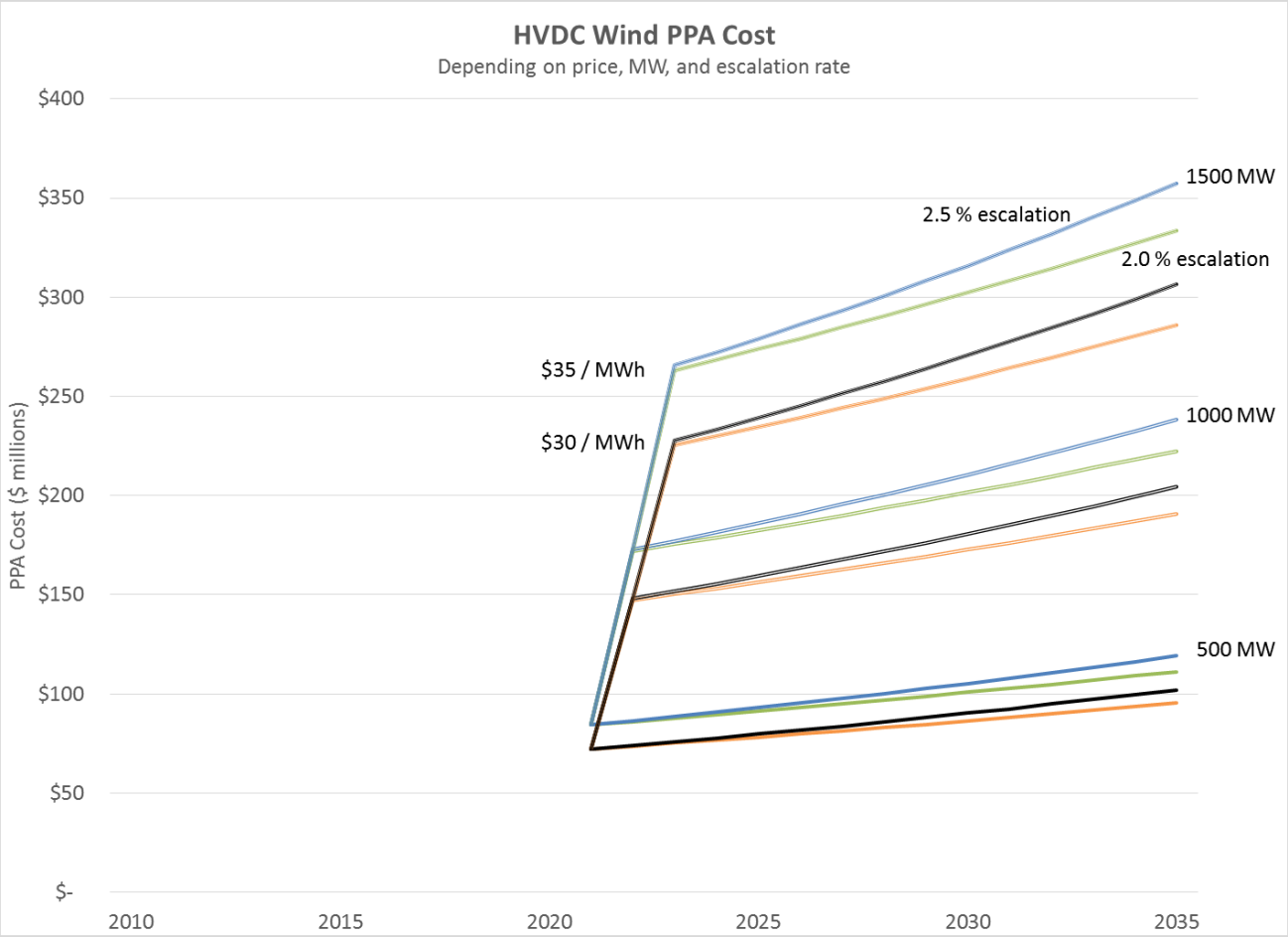


Impact of cost assumptions on total PPA cost to TVA

Twelve projections of total cost are shown

- Three levels of MW purchase by TVA
- Two cost assumptions
- Two escalation rate assumptions

Subsequent pages will focus on $30 / MWh with 2.5% cost escalation, reflecting a mid-range assumption.

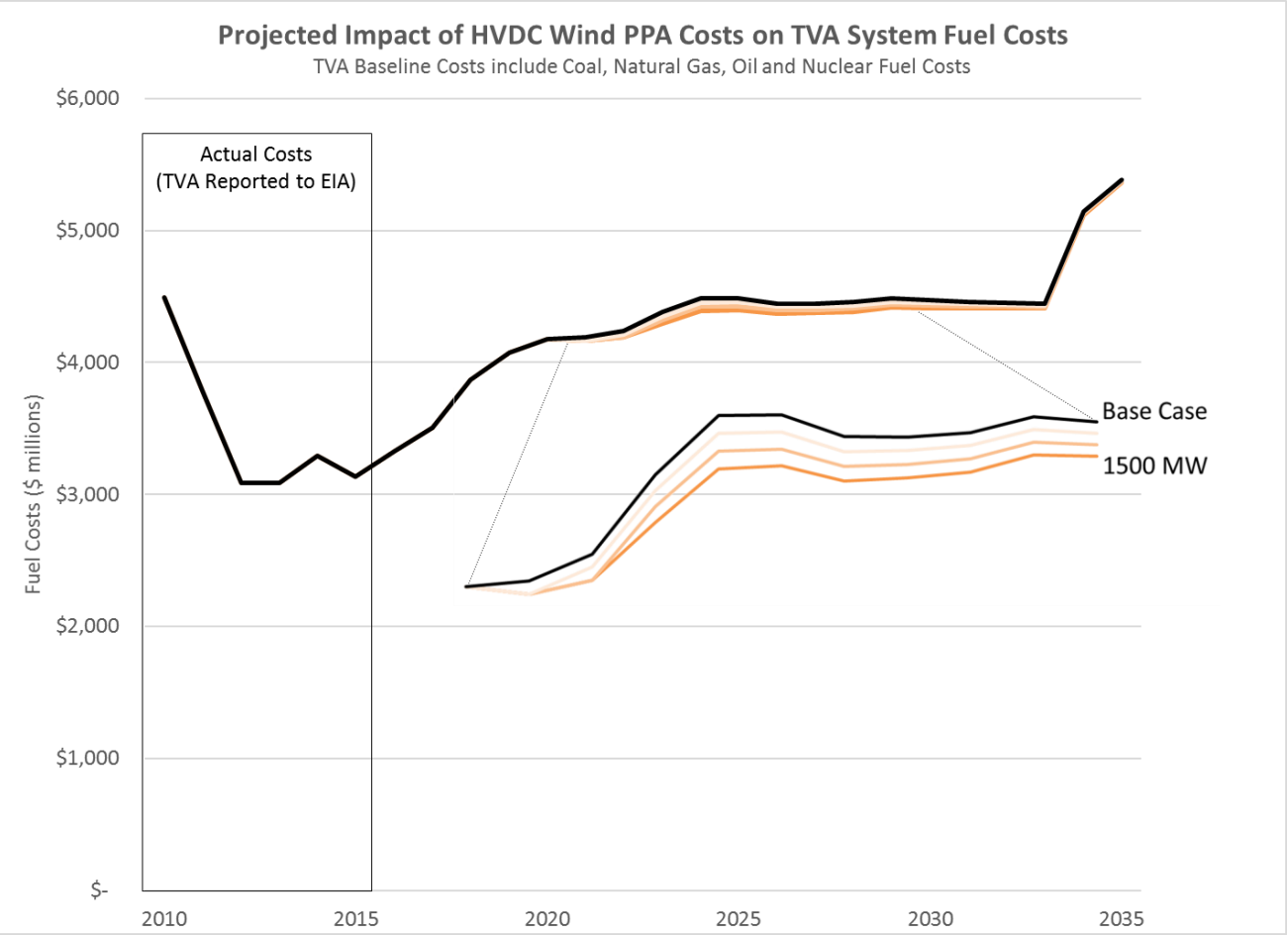


Comparison of Clean Line wind PPA costs to natural gas fuel costs

This graph highlights the net impact of varying levels of Clean Line wind capacity contracts on TVA's fuel costs. During the first five years of full operation, TVA could save as much as $136 million per year.

As previously noted, for simplicity, a cost of $30 /MWh and an escalation rate of 2.5% per year is assumed. Under these assumptions, net fuel cost savings would be about $60 million/year for 1000 MW.

The increase in total system fuel costs in 2034 is related to a planned shift from nuclear and coal to gas or off-system power.



Corroboration by independent experts

Leidos Engineering simulated the impact of the Clean Line project on energy production costs for the US Department of Energy. Assuming the line would operate fully in 2019, the project would save $742 million and reduce TVA energy costs by $1.44 / MWh.

Production Cost Savings ($ Million)

	Tennessee	Arkansas	Rest of Eastern Interconnect
Without P&E	2,025	1,612	72,192
With P&E	1,887	1,547	71,653
Savings	137	65	540

Marginal Price of Energy for TVA Demand ($/MWh)

	On Peak	Off Peak	Average
Without P&E	37.03	32.81	34.88
With P&E	36.05	30.93	33.43
Change	-0.98	-1.89	-1.44

Locational Marginal Price for Entergy Demand ($/MWh)

	On Peak	Off Peak	Average
Without P&E	39.08	32.38	35.66
With P&E	39.08	32.11	35.52
Change	0.00	-0.27	-0.14

Source: Leidos Engineering, "Plains & Eastern Clean Line Benefit Analysis," Letter to Clean Line Energy Partners (January 7, 2015). https://energy.gov/sites/prod/files/2015/04/f22/CleanLinePt2-Appendix-2-G.pdf

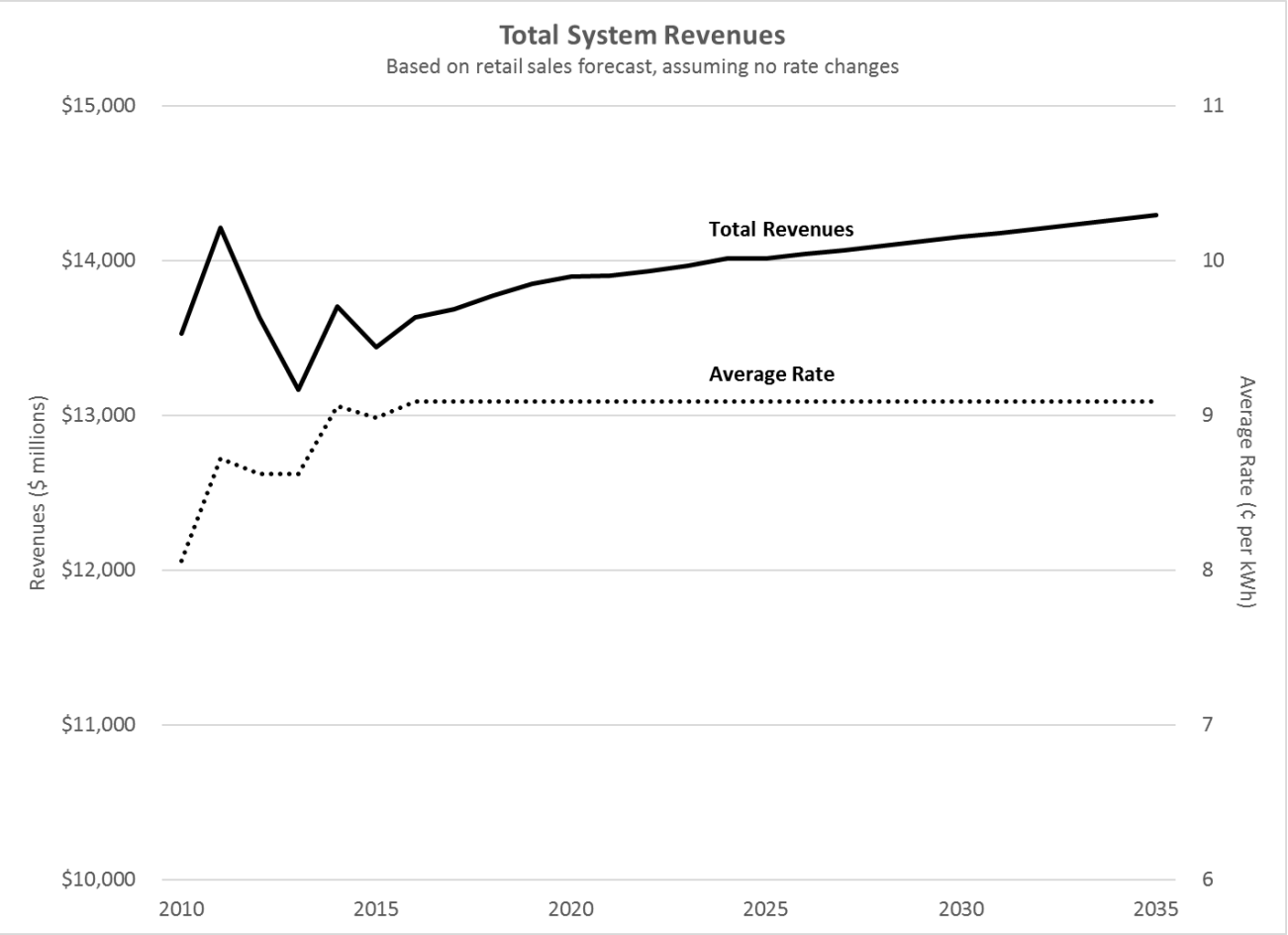
Impact of Clean Line on TVA rates

Clean Line will have a small but beneficial impact on TVA rates, saving 0.05 to 0.15 ¢/kWh. Rate savings are small because Clean Line would meet just 1-4% of TVA demand.

Simple TVA retail revenue projection (Does not include any fuel cost adjustments)

Assuming a simple TVA retail revenue projection, based on retail sales forecast and existing average rates.

Rates are calculated based on reported revenues divided by retail sales. Thus, this analysis is not based on any specific customer rate structures.



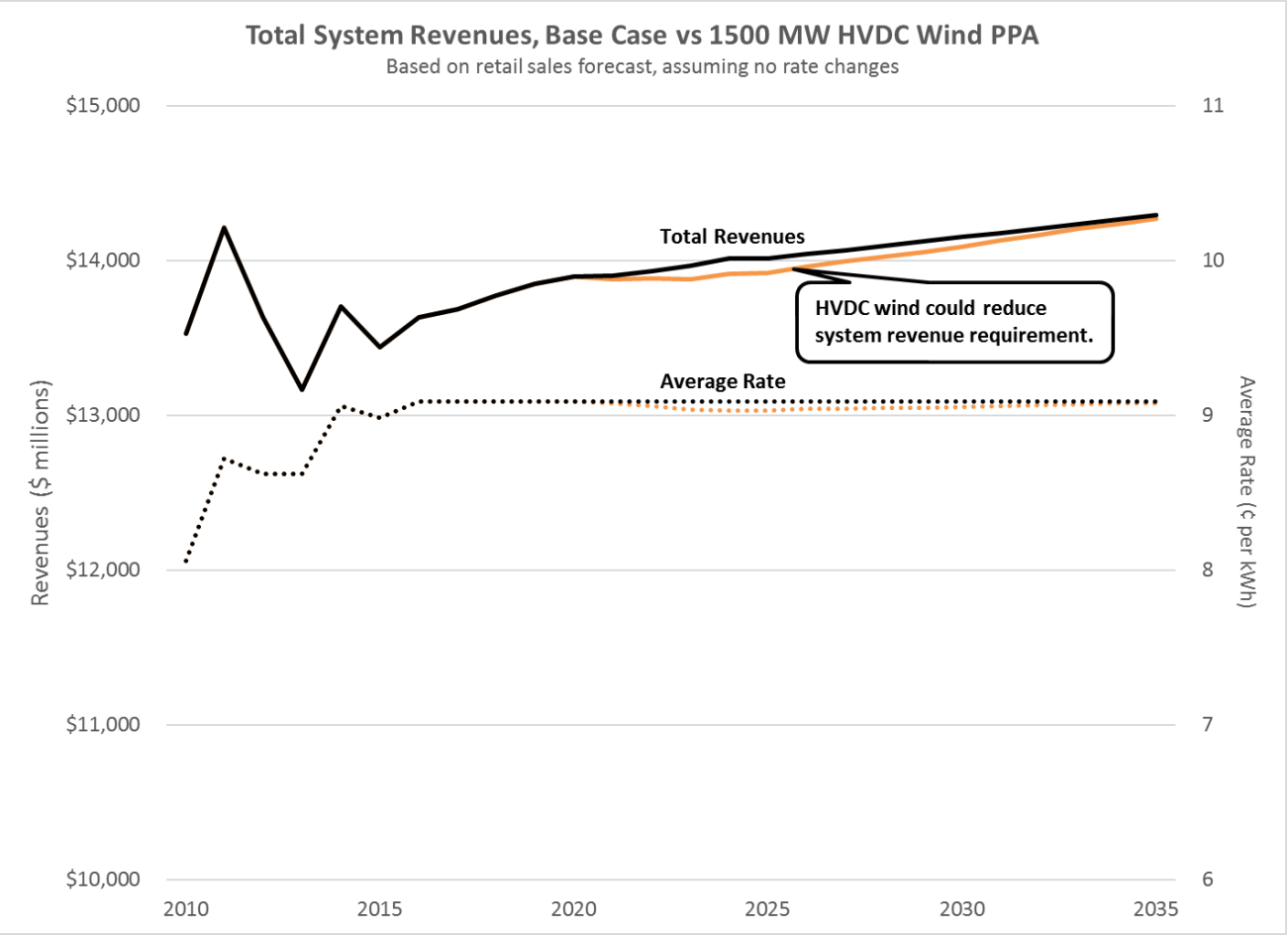
Rate impact of HVDC wind PPA costs and natural gas fuel cost savings

This graph illustrates the impact on TVA's retail revenue requirement and average rates of two changes to TVA's costs: increased cost due to HVDC wind PPA contracts, and decreased cost due to reduced natural gas fuel purchases.

The projected impact is a small net savings, as illustrated by the orange line; the base case is in black.

Based on retail sales forecast and existing average rates, a 1500 MW HVDC wind PPA could reduce system rates by about 0.06 ¢/kWh.

This analysis is not based on any specific customer rate structures.

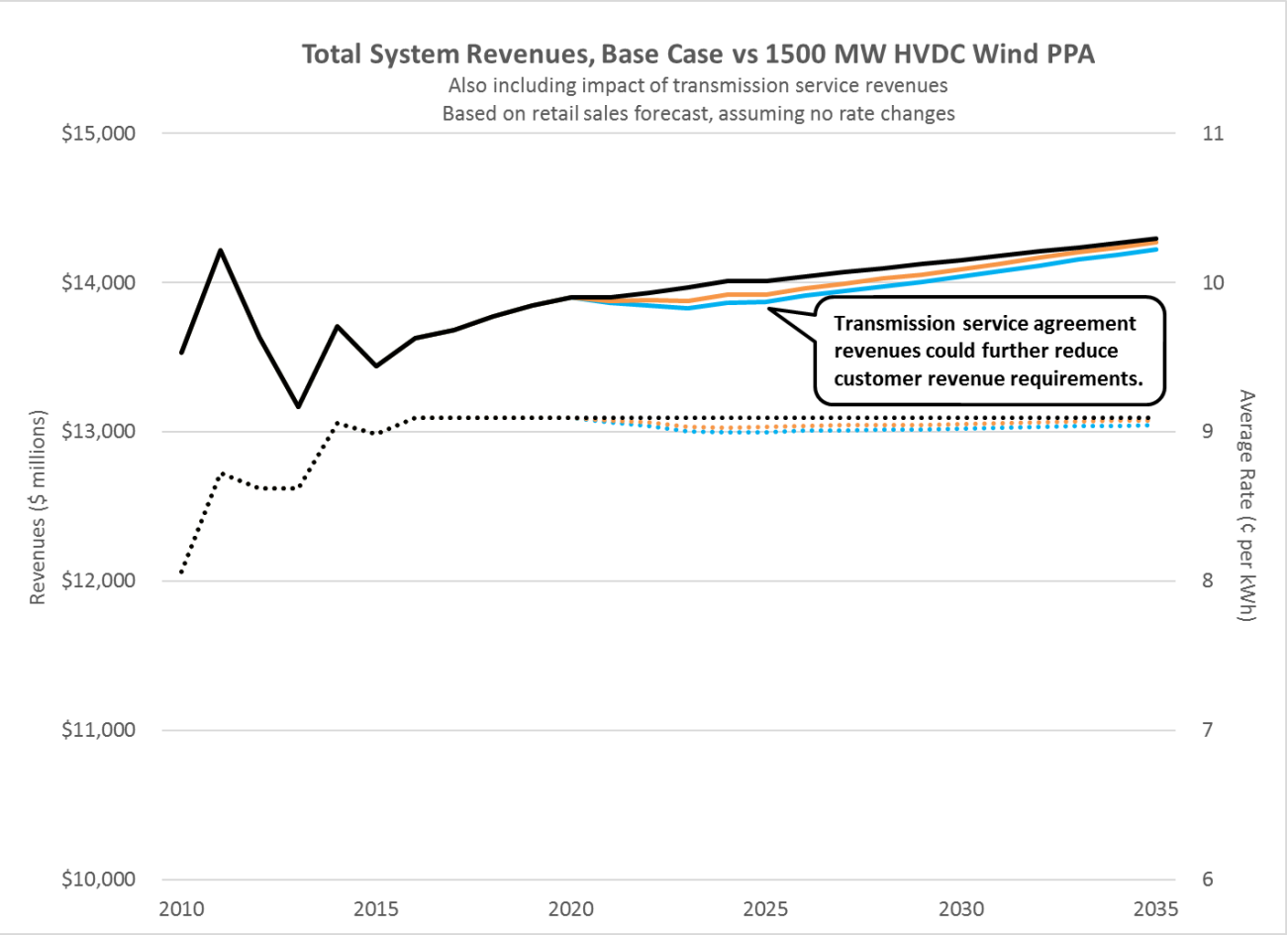


Impact of transmission service revenues on TVA revenue requirement and rates

Clean Line anticipates that TVA will earn increased transmission service revenues. These revenues will be associated with deliveries of HVDC wind to other PPA customers in the southeast.

These revenues will vary depending on transaction details. For this analysis, the benefit is assumed to be $7 per MWh for a 1500 MW PPA.

These revenues could ensure that the Clean Line project would be a net financial benefit to the TVA system. The system rate reduction could increase from about 0.06 to about 0.09 ¢/kWh.



Natural gas fuel cost sensitivity (2016-2035)

	Lower cost	**Higher cost**
Natural gas fuel cost	- 50%	+ 50%
Natural gas fuel cost, 2025 ($/MWh)	$ 22.88	$ 68.63
Natural gas dispatch	+ 20%	- 20%
Coal dispatch	Reduced to balance	Increased to balance

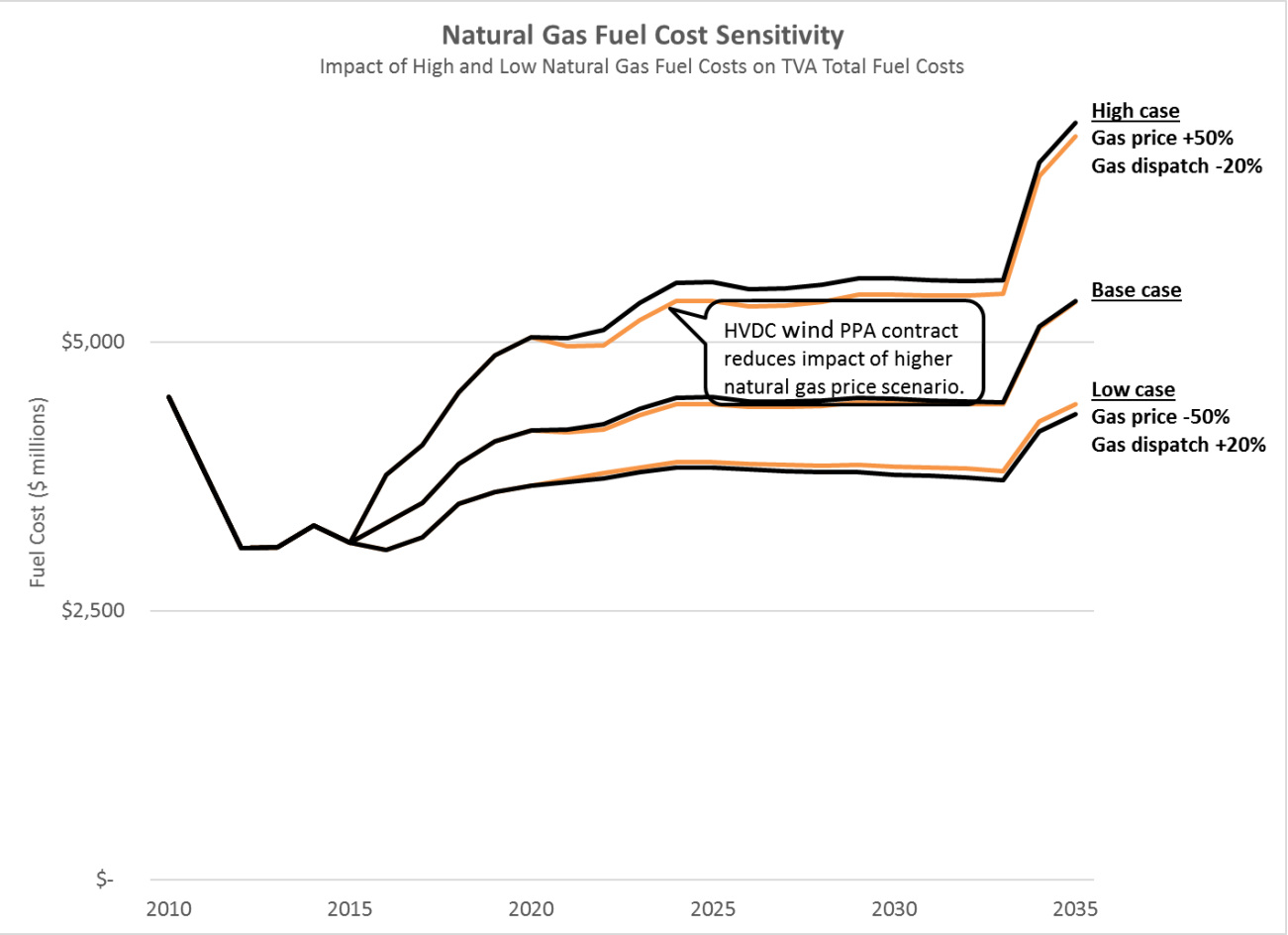
Potential impact of natural gas price risk

TVA's total fuel costs are very sensitive to natural gas fuel costs and dispatch rates.

Under higher natural gas costs, the savings associated with a 1000 MW HVDC wind contract increase.

Lower natural gas costs would result in TVA system fuel costs increasing, but by less than the increase under the high cost scenario.

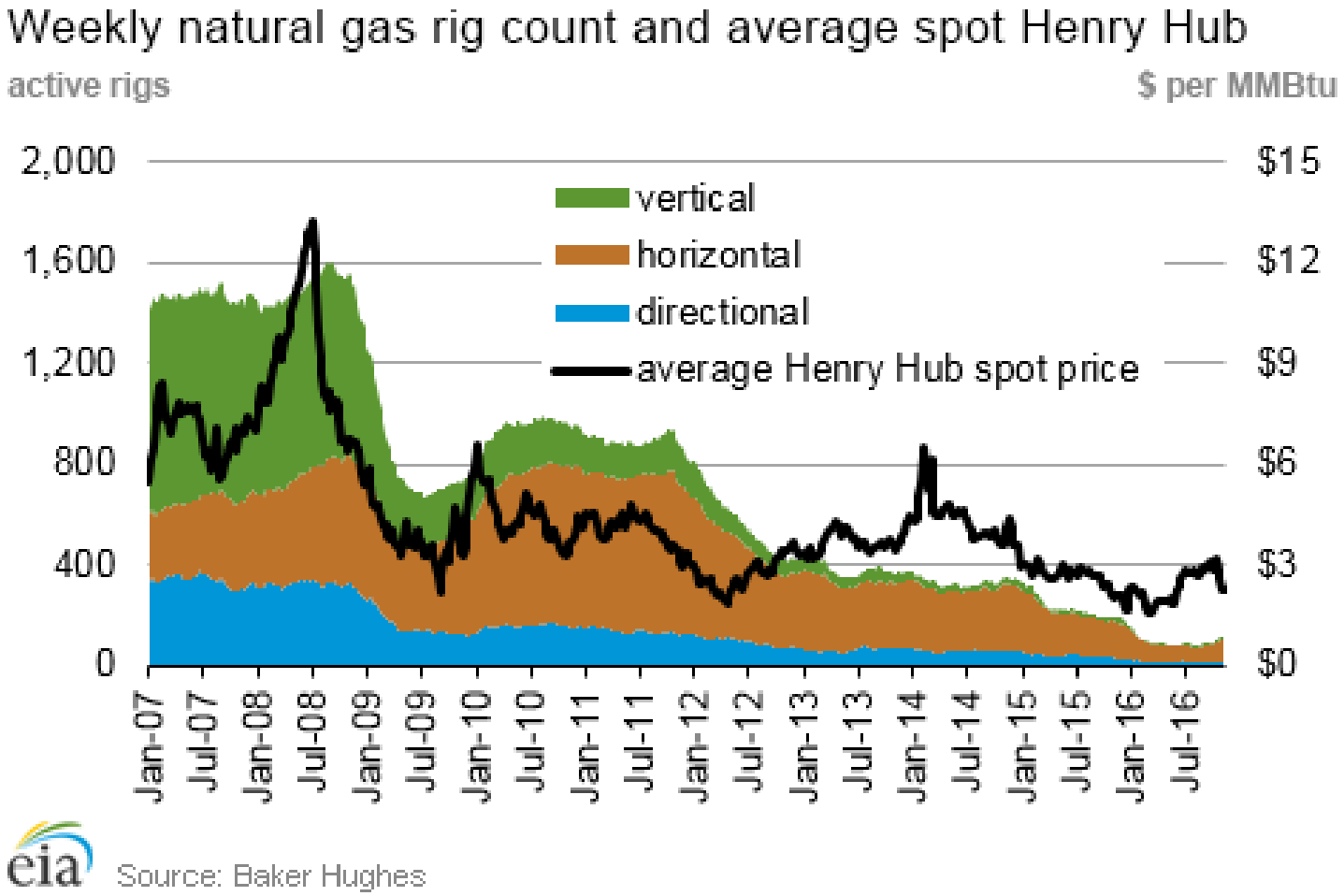
Rate savings (not shown) increase to over 0.1 ¢/kWh in the high natural gas cost scenario.



Natural gas prices are not likely to decline

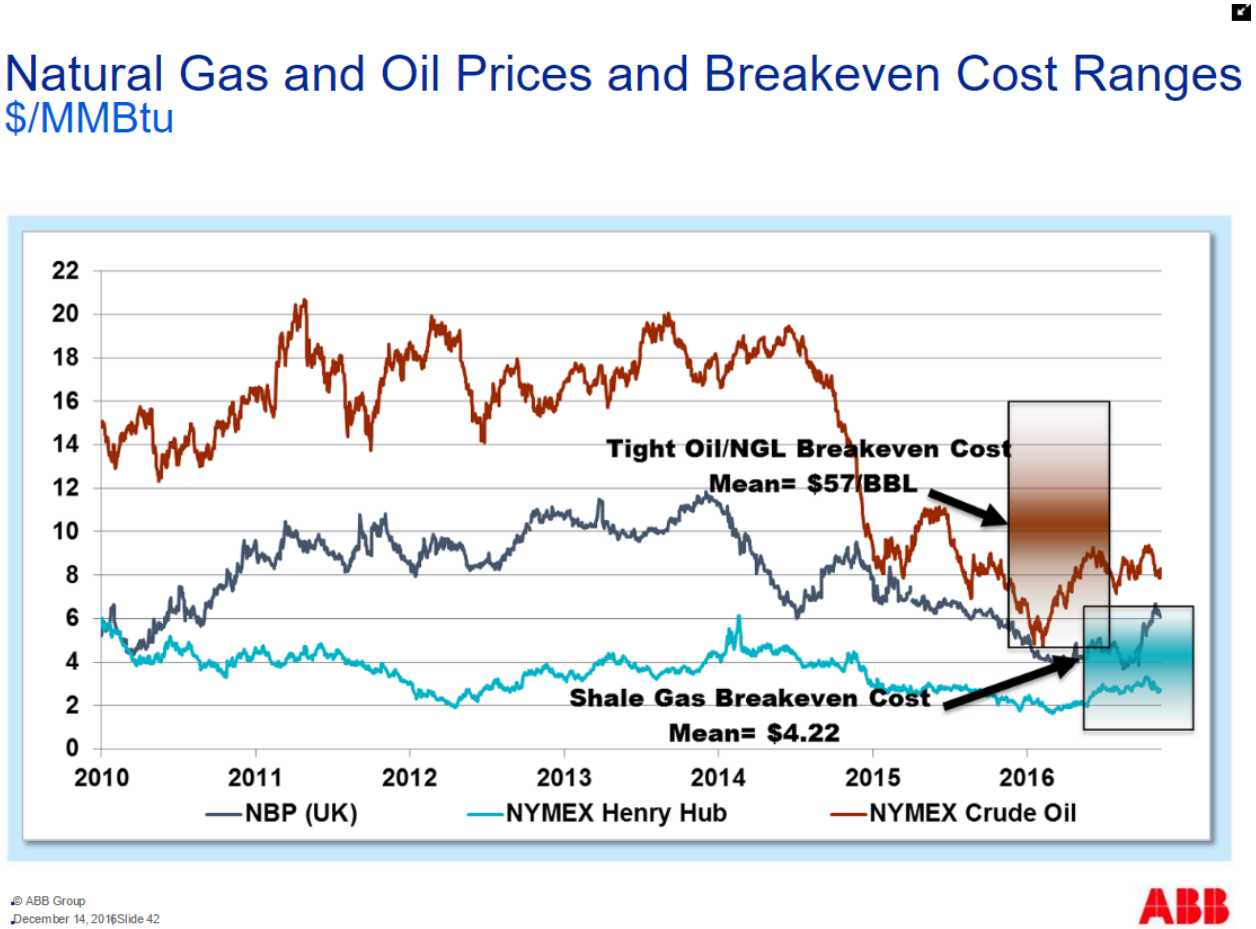
While markets are uncertain, natural gas prices are not likely to drop by 50% on a sustained basis.

As illustrated at right, natural gas drilling is at a 10-year low.



Natural gas and oil prices are generally below breakeven costs today

Unless oil and gas production costs decline, there is little reason to think that oil and gas production will be sustained at prices at or below today's levels.



Conclusion: Clean Line wind is likely to save money for TVA, but under any scenario average system rates will be virtually unaffected.

- TVA's fuel costs are likely to go down if Clean Line wind PPA costs reflect the assumptions in this analysis
  - Benefits increase due to transmission service agreement revenues
  - Benefits increase even more if natural gas fuel costs are above projected values
- TVA rates would increase <u>only if</u> natural gas fuel costs drop below the lowest recent annual average and remain at that level during most of the next two decades.
- Under any of these scenarios, HVDC wind contracts of 500 – 1000 MW would have a <u>small rate impact</u>: no more than 0.15¢ per kWh in either direction.
  - Rate savings are limited because Clean Line would supply only 1-4% of TVA's power needs.

Other benefits of Clean Line to TVA

Clean Line will include upgrades to TVA's internal transmission system, enhancing system reliability. Clean Line will provide a substantial amount of power during peak hours, also enhancing system reliability during peak hours.

Clean Line includes more than just wind power delivery

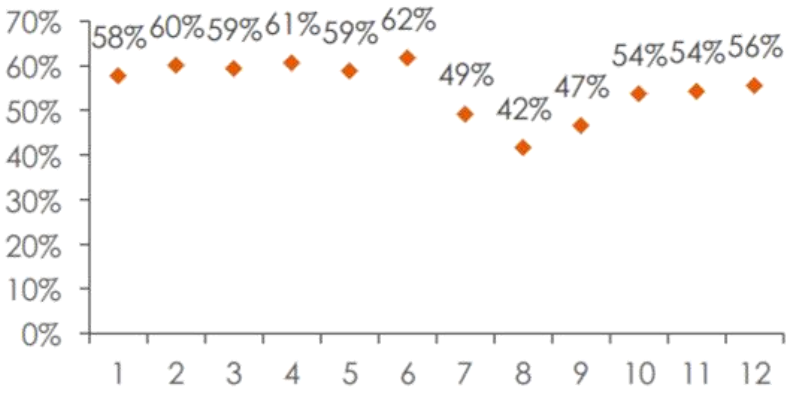
- The Clean Line Plains & Eastern project includes a commitment to build approximately 37 miles of 500 kV transmission between the Lagoon Creek and Jackson substations.
- In addition to carrying power delivered via the HVDC project, the 37 mile AC transmission facility will provide additional reliability benefits to TVA.

Capacity benefits of Clean Line wind

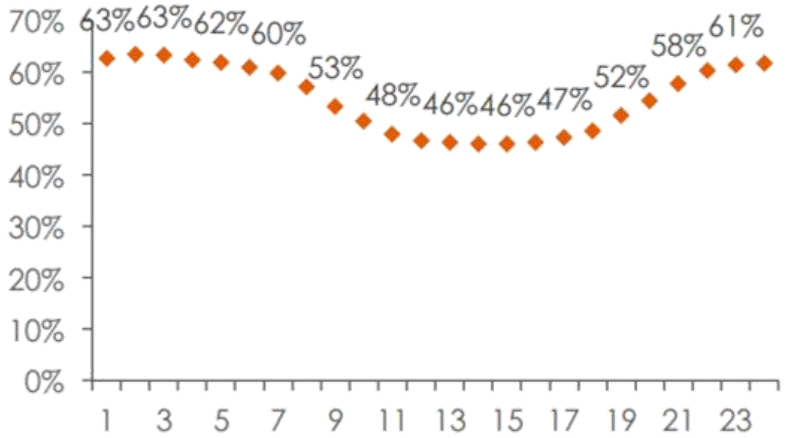
- Clean Line wind power from western Oklahoma could provide substantial power during TVA's peak demand periods. Power delivered during these periods enhances system reliability, reduces the need to maintain expensive power plants, and defers the need to acquire other power capacity.
- TVA's 2015 Integrated Resource Plan used a uniform evaluation of wind resources with respect to contribution to on-peak demand during the summer peak. This resulted in a 14% dependable capacity credit, referred to as "NDC."
  - A 1,000 MW wind resource would have a NDC of 140 MW.
- TVA's IRP 14% annual NDC is based on "current wind contracts," and does not consider advantages indicated by data supplied by Clean Line. In the IRP, TVA stated, "A more specific NDC would be incorporated into the wind portfolio NDC calculation <u>once specific sites are known</u>."
  - TVA has not publicly indicated what NDC is views as appropriate for wind resources delivered via HVDC transmission.

9 m/s wind speed sites are abundant in the Oklahoma Panhandle

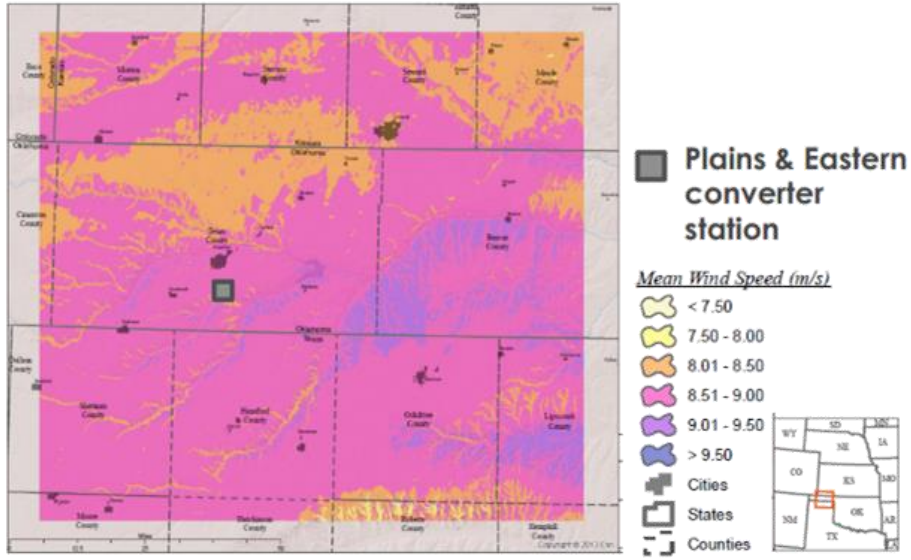
Oklahoma Panhandle wind seasonal profile[1]
Average monthly capacity factor vs month



Oklahoma Panhandle wind diurnal profile[1]
Average hourly capacity factor vs hour



Oklahoma Panhandle wind map



9 m/s sites are abundant in the 100x100 mile area around the Plains & Eastern Clean Line converter station

Plains & Eastern will unlock a wind resource with **average capacity factors of approximately 55%**

1. Plains & Eastern generation profile is derived from 3Tier simulated wind speed data in the Oklahoma Panhandle applied to Vestas V110-2.0, V126-3.3, and GE2.0-116 turbine power curves

CLEAN LINE ENERGY PARTNERS

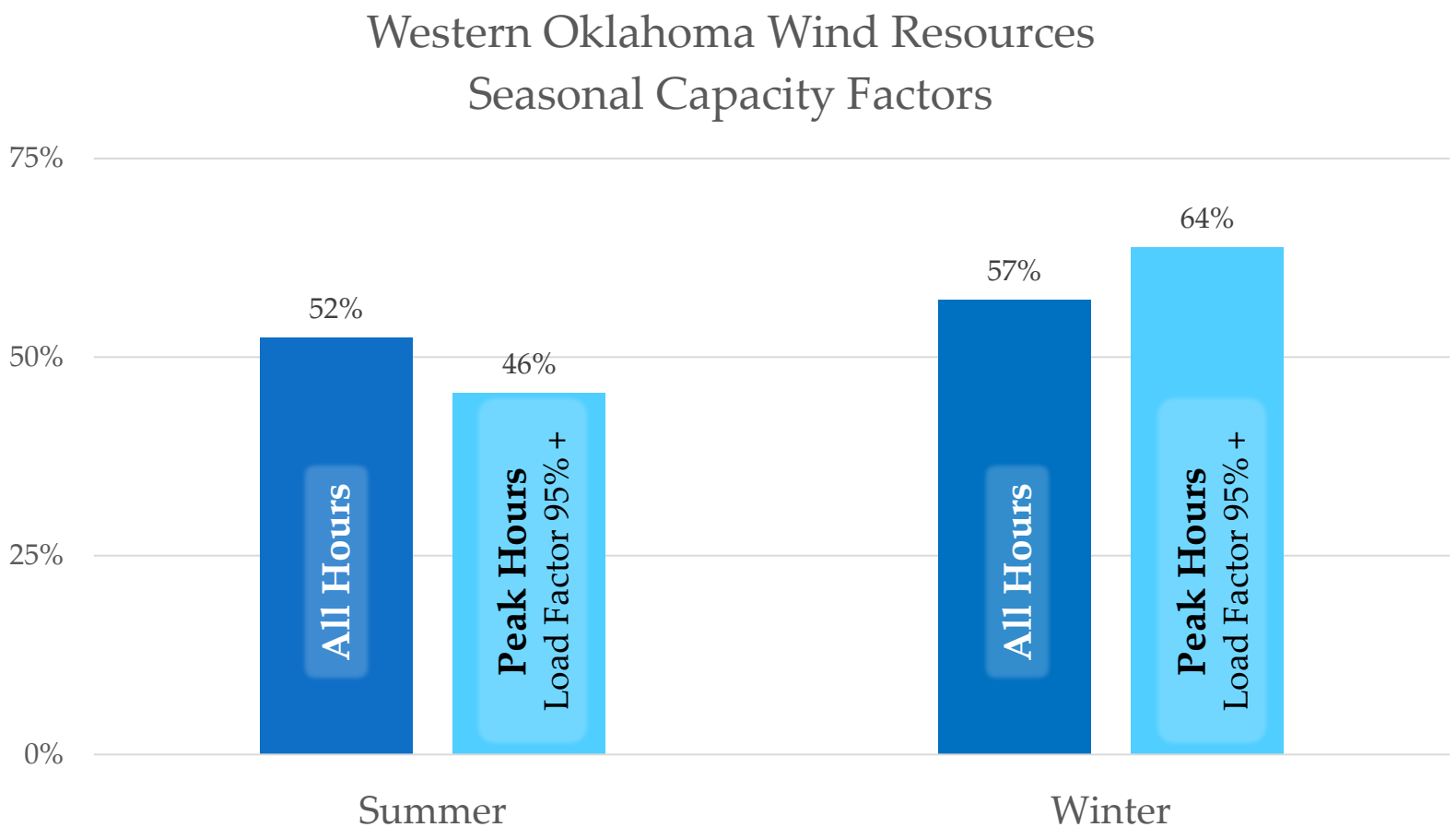
TVA can depend on Clean Line wind

Especially during winter months

Wind resources in western Oklahoma perform well around the year. Monthly capacity factors are anticipated in the 40-60% range.

During TVA system peak events (hours in which the system load factor is 95% or greater), HVDC wind shows seasonal differences. During summer peaks, output is slightly below average, but during winter peaks, above average.

These data reflect a comparison of wind generation simulations by 3Tier as compared to TVA system load factors over the 1998-2012 period.



Three ways TVA could quantify the capacity benefits of Clean Line wind

- TVA could assign a financial benefit to HVDC wind based on dependable capacity and the cost of capacity
  - Assuming 40% NDC and $100 per kW-year (peaker cost), the benefit of HVDC wind would be $40 per kW-year.
  - Based on this benefit assumption, for a 1000 MW PPA, TVA would save an additional $100 million per year beyond the $60 million in fuel cost savings.
- TVA could consider the retirement of existing capacity to avoid future capital expenditures. The benefit of HVDC wind would be based on those capital expenditures avoided, less any additional costs to maintain system reliability.
- TVA could consider the additional benefit of highly-reliable winter renewable energy deliveries. During "polar vortex" conditions, HVDC wind could provide a substantial enhancement to TVA system reliability. A value could be assigned through a reserve margin analysis, including consideration of reduced need to rely on off-system resources.