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Why a smart energy policy can include coal

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A pulverized coal plant in the US is an example of how combining the right operational model with best-in-class technologies can produce affordable, reliable and secure power with the lowest possible environmental impact, write ***Robert Giglio and Steve Nelson***

Longview Power's 770 MWe coal power plant in West Virginia

Credit: Longview Power

While energy policymakers and power industry leaders have differing views on how to move toward a clean, reliable and affordable power delivery system, they all agree on one thing: that a portfolio of fuel and technology options is the best strategy to meet our future energy needs while enduring the continued uncertainty inherent in the energy sector.

The corollary is even more important – that over-reliance on a single technology or fuel can have devastating impact. This can be seen today in Japan's power industry after the Fukushisma nuclear accident, in oil exporting countries with oil prices more than half the value they were a year ago, and in the US when heavy frame gas turbines were being sold on eBay at rock bottom prices after the collapse of the combined-cycle build boom in 2006.

All technologies and fuels have their advantages, disadvantages and carry risk. For pulverized coal, its advantages are low cost, large scale, reliable power. Its disadvantage has been – and continues to be – its environmental footprint. However, taking a closer look at recent new pulverized coal plants coming online, like Longview Power's 770 MW plant in West Virginia, the reality is not matching the headlines we see in the media.

The Longview project

The Longview project is a good example of combining the right operational model with best-in-class technologies to produce very affordable, reliable and secure power with the lowest environmental impact. Longview Power teamed with affiliated mining company Mepco to build an integrated coal-mine-to-power energy complex in Maidsville, West Virginia, in the US.

The power plant is located within 8 km of the coal mine which produces high sulphur bituminous coal primarily for the Longview power plant. The power plant began commercial operation in December 2011 and has a rated net capacity of 700 MW and a gross capacity of 770 MW.

The plant is owned by major private investment companies and employs over 600 skilled local workers annually, and adds approximately $43 million per year to the local economy in terms of indirect employment and material supply. Due to its mine-mouth project structure and its high power plant efficiency, the plant is among the lowest cost generator in the US, and the world for that matter. Its marginal generating cost is lower than all the natural gas combined-cycle and nuclear power plants on the PJM grid that it serves. As shown in Figure 1, its marginal cost is even below most of the hydropower plants on the PJM grid, with only wind and solar dispatched in front of Longview.

STEAM CONDITIONS	Metric units	English Units
Main steam flow rate	2362 t/hr	4876 kpph
Main steam temperature	569˚C	1056˚F
Main steam pressure	258 bar	3735 psia
Reheat steam flow rate	1871 t/hr	4012 kpph
Reheat steam temperature	557˚C	1052˚F
Reheat steam pressure	55.3 bar	788 psia
POWER GENERATION		
Gross output	770 MWe	
Net output	700 MWe	
POWER PERFORMANCE		
Net plant efficiency %	41.3 LHV	39.5 HHV
Net plant heat rate	8726 kJ/kWh	8640 Btu/kWh

Table 1 . Longview's steam and plant performance values at full load design conditions

With this cost profile, it is no wonder why Longview produced 98.5 per cent of its total rated power production since completion of recent repairs, and why Longview Power is aiming to achieve a 92 per cent capacity factor for 2016.

One key factor in achieving this low level of electricity production cost is due to a very low fuel cost. Since Mepco is an affiliated company, the coal price is negotiated for the benefit of both companies and operational enhancements are developed continuously. Further, the coal travels from the mine to the power plant on a 7.2 km conveyor, avoiding the higher staff, equipment, fuel and maintenance cost of trucks, trains, roads and tracks that most other coal plants carry.

Another key factor is related to Longview's recent efforts to optimize plant efficiency and achieving a very high net plant efficiency of 39.5 per cent (fuel HHV basis), which allows the plant to produce full power while consuming 17.5 per cent less fuel than the average coal plant in the US. This, in itself, saves Longview over $10 million per year in the plant's operating cost.

Clean and efficient power

The Longview plant is subject to very strict environmental standards. In fact, the state of West Virginia imposed on Longview the lowest NOx, SOx, PM, CO and mercury emissions limits ever imposed on a coal plant in the entire US.

The plant consistently meets all permitted emissions and is now the cleanest operating coal power plant in the PJM power market and one of the cleanest in the US. As Figure 2 shows, Longview's' permitted stack emissions are many times lower than other coal plants in state of West Virginia. Further, as Figure 3 shows, the plant's actual stack emissions are also well below the limits of the EPA's strict Mercury Air Toxins Standard (MATS).

Due to Longview's high net plant efficiency, the plant's actual emissions on a tonne/year or mg/MWh basis are reduced by another 17.5 per cent as compared to the average coal plant in the US. This not only applies to SOx, NOx, PM, CO, and mercury air emissions, but also to CO2, as well as all solid and liquid waste streams from the plant, the coal mine and the fuel delivery system.

The mine-mouth project structure itself provides other environmental benefits. The power plant is designed to burn run-of-mine coal, avoiding the waste water streams and coal tailings associated with coal washing, which is a common practice in many coal mines and plants around the world. In fact, at Longview, no waste water from any part of the plant or mine is discharged to surface waters.

Since a conveyor transports Longview's coal to the plant, truck and train emissions, road dust, and noise are completely avoided. A significant portion of boiler fly ash is sold for beneficial use and the remaining portion is dry landfilled on site, again minimizing truck and train traffic through local communities where people enjoy the peace and quiet of the country while utilizing Longview's power for their homes, schools, farms and businesses.

Technology matters

Technology is a big part of Longview's best-in-class performance. To achieve its high plant efficiency and reliability, the power plant utilizes a unique low mass flux, vertical-tube, supercritical pulverized boiler supplied by Amec Foster Wheeler. This is the only supercritical pulverized coal plant in the US and among only a few in the world that use this advanced coal boiler technology.The Amec Foster Wheeler PC boiler utilizes supercritical steam conditions (steam pressures above 221 bar or 3206 psia) which allows the steam to absorb more heat from the burning fuel, resulting in higher plant efficiency.

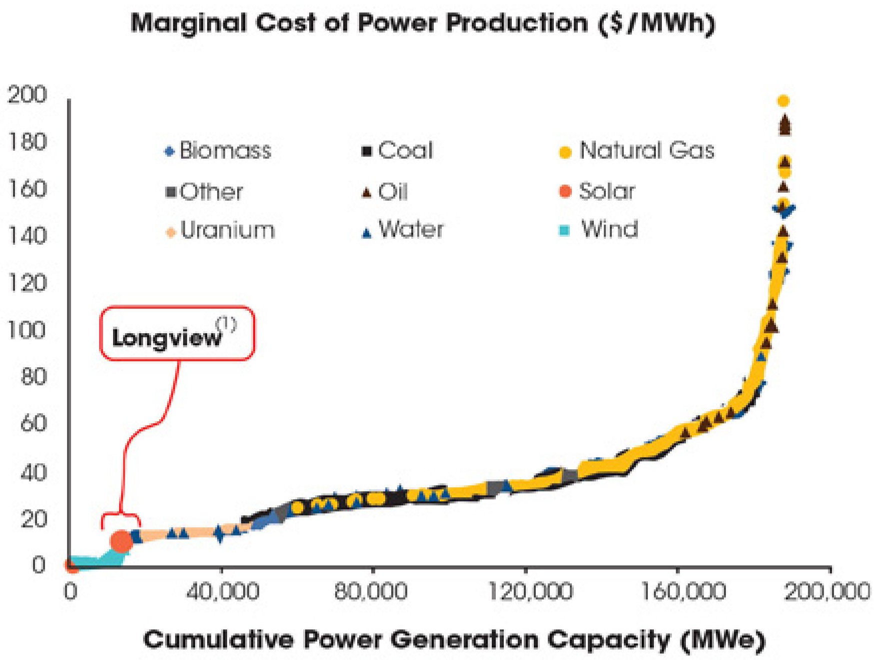

Figure 1. Dispatch merit curve for PJM grid served by Longview

It is the supercritical steam condition that allows Longview to achieve its very high plant efficiency of 41.3 per cent/39.5 per cent based on the coal's lower/higher heating value. Longview is the most efficient operating coal plant in the US, giving the plant its best-in-class emissions levels and cost competitiveness. Table 1 shows Longview's steam and plant performance values at its full load design operating conditions.

Nearly all supercritical sliding-pressure boilers angle and wrap the tubes containing water and steam in a spiral or helix pattern to form the lower section of furnace walls, as illustrated in Figure 4. This is done to even out tube-to-tube temperature differences and mechanical stresses that occur between the tubes near the burners, which receive an intense level of heat, and those much further from the burners receiving much less heat. Under supercritical steam pressures, the temperature difference and associated stresses can be significant and overtime can virtually tear the tubes apart and cause them to fail.

But what makes Longview's boiler so different than all the other supercritical sliding-pressure boilers is that its entire furnace is formed with only vertical tubes which carrying a very low mass flux of steam and water (under 1000 kg/m2-s). This is a much simpler design that costs less to build and is easier to repair and maintain.

The boiler is simply hung from top supports with the vertical boiler tubes playing a dual role of supporting the boiler and producing steam. For spiral designs, since the tubes wind around the furnace in a helix pattern, they want to untwist if supported only vertically and require a more complex furnace support system which is more costly, heavier, and requires special bracing when repairing furnace tubes.

Further, the steam has a much shorter distance to travel in the vertical tube design to reach the top of the furnace, as compared to the longer path of the spiral tube design. The shorter tubes and the low mass flux allow the vertical design to have a much lower steam pressure drop, which translates into lower boiler feedwater pumping power and higher net plant efficiency.

Spiral designs typically incur an additional 10 bar or 145 psia steam pressure loss across the furnace, which translates into about 1 MW of additional boiler feed water pump power consumption. At $50/MWh this loss can translate into annual lost power sales revenues of about $432,000, and can add up to a $6.6 million NPV over the life of the plant.

To overcome the tube-to-tube temperature and stress problem, the Amec Foster Wheeler vertical tube boiler design uses a much smaller tube diameter which carries much less water and steam. This allows buoyancy forces within the water and steam in the tube to become stronger, causing the water and steam flow to increase and provide additional cooling to the tubes receiving more heat.

This provides a passive self-cooling protection mechanism limiting the temperature and stress between tubes and across the furnace walls. As an added protection, the inside of the tubes receiving high heat are grooved or rifled with a spiral pattern to enhance tube cooling.

These design enhancements add up to a safe, low maintenance, highly reliable, long life boiler.

Smart emission control

Using the simple principle that it is much less costly to prevent NOx from forming in the first place than it is to reduce it afterwards, the firing system of the Amec Foster Wheeler boiler has many advanced and innovative design features. Mill fineness control, combustion air control to each windbox and each burner, staged low-NOx combustion and over-fire air technologies are utilized to achieve very low NOx levels leaving Longview’s furnace.

In addition to ultra-low CO emissions, this minimizes the reduction needed by the SCR system, which has a large long-term cost benefit over the life of the plant when considering ammonia consumption and catalyst replacement cost.

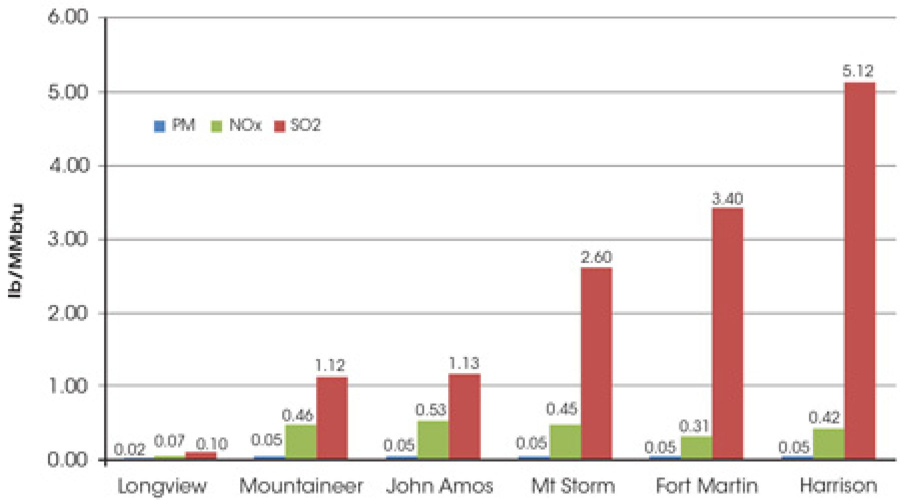

Figure 2. Permitted title V operating and acid rain emission limits for coal plants in West Viginia

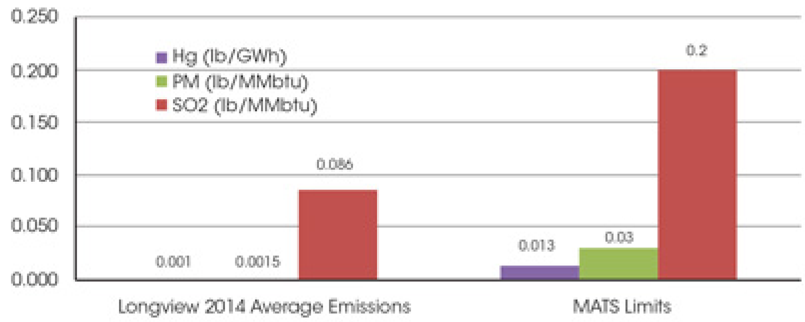

Figure 3. Longview's actual stack emissions are well below MATS limits

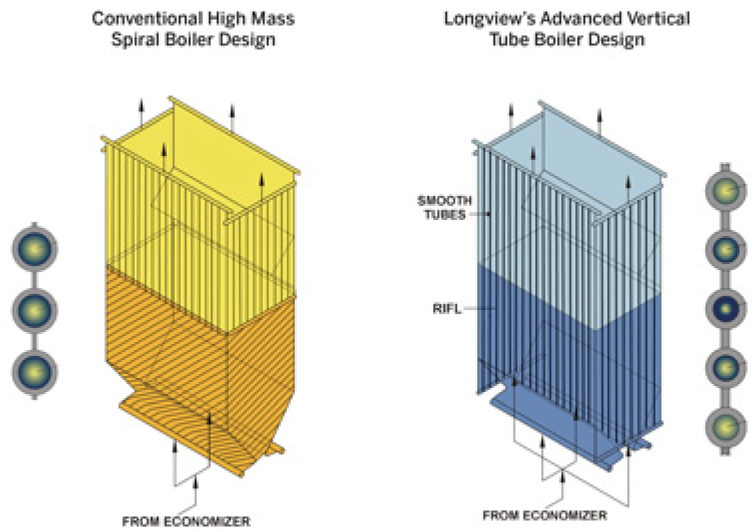

Figure 4. Conventional sprial vs vertical tube furnace design

For example, the burner wind-boxes are compartmentalized between each of the sic burner rows (three rows on each side of the opposed wall-fired boiler). A system of air dampers, flow measurements and control logic is designed so that air flow can be controlled to each burner row as well as biased from side to side within each row. This degree of measurement and controls dedicated to reliably and effectively controlling air/fuel ratio, CO, and NOx is truly unique and not reliably accomplished in many other coal plants.

Instead of using the typical ESP + Wet FGD scrubber configuration behind the boiler, Longview utilizes a DSI + Fabric Filter + Wet FGD scrubber with two dual flow trays. This configuration provides best in class removal rates (e.g., 99.5 per cent SO_2 removal), fuel flexibility and redundant systems (facilitating on-line maintenance) to control multiple pollutants most cost-effectively.

The dry sorbent injection system (DSI) can utilize a range of sorbents to control metals and acid gases in the vapour phase by adsorption onto solid ash particles. The fabric filter captures these particles as well as the boiler's fly ash to levels well beyond an electrostatic precipitator (ESP). The dual flow trays in the wet FGD expand the FGD's capacity to capture all acid gases.

All of these systems are designed with flexibility in mind to endure continued tightening US environmental regulations and changes in fuel quality over the long life of the Longview energy complex.

The Longview energy complex sets a new level of best-class performance for today's modern coal power solutions. It demonstrates a solution for safe, secure, reliable and affordable coal power with minimal environmental impact.

Today, coal produces about 40 per cent of the world's electricity, the largest share from any source. In 30 years from now, nearly all long-term forecasts show that coal will still produce about one-third of the world's electricity. At the global level, this supports the smart strategy of keeping a diverse portfolio of generating options.

In order to maintain this level of coal, forecasters estimate that between 1500 GW and 2000 GW of new coal plants will be built over the next 30 years to meet growing electricity demand and to replace aging coal plants.

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