New-tech American Coal-fired Electricity for Africa: Clean Air, Indoors and Out

CO2 COALITION

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Executive Summary

African factories and businesses suffer frequent electrical power outages, and only a third of Africans have access to reliable electricity at home. This limits economic growth, and life expectancy is 15 years behind developing countries that have made the transition to universal electrification. Forced to cook, light, and heat their homes with wood, charcoal, and animal dung, over 400,000 Africans die each year from respiratory diseases caused by indoor air pollution.

Universal electrification will help solve Africa's problem of indoor air pollution, and reduce the outdoor health risks of the recent "dieselization" of Africa. Soot-spewing backup diesel engines kick in when the grid goes down, and many countries spend more on dirty backup power than on the electrical grid itself. However, emissions from Africa's continuing coal-fired generation of electricity could at the same time add to illness and mortality from outdoor air pollution, as was the case in China's dramatic 30-year transition to universal electrification.

Africa is projected to double its electricity capacity in the next 20 years. "Renewable" electricity from wind and solar with battery storage is not mature or reliable enough to meet this demand. Electricity from natural gas and oil are expected to be part of the solution, but the infrastructure for moving gas and oil to power plants is in most countries too costly to build and maintain.

There is a strong consensus among power analysts that Africa's cheap, abundant, easily transportable coal will continue to be used on a large scale for electricity. Without modern "scrubbing" and other technologies to neutralize pollutants, Africa could be trading one health crisis for another.

U.S. policy at present opposes coal-fired electricity in Africa. Obama administration policies, based on concern about emissions of the non-polluting greenhouse gas carbon dioxide (CO_2) and their possible future impact on extreme weather, continue to guide U.S. policy. The U.S.-funded World Bank and African Development Bank no longer support coal plants, preferring plants using natural gas, which produces about half the CO_2 emissions of coal per unit of energy. The U.S. Power Africa program has taken the same stance. This leaves the construction of coal plants to China and others who have scrubbing technology but do not require it in their foreign construction.

American "new-tech" electricity generation and pollution scrubbing is in operation at the Turk Plant in Arkansas. A field visit and interviews by the CO2 Coalition confirm that the technology virtually eliminates health hazards from sulfur dioxide, nitrogen oxides, and particulate matter. Water for the boiler, cooling for re-use, and scrubbing comes from a nearby dammed river, and much is re-used and recycled. However, no similar plants are under construction in America because of the fall in natural gas prices due to another remarkable American technology, "fracking."

Could this American technology work in Africa? After all, Africa is littered with "white elephants" – projects that worked well in developed countries but were not transferable to Africa's physical, infrastructure, regulatory, political, and economic spheres. The answer is a qualified "yes" – for a few test cases at first with supportive governments with viable plans for maintenance and pricing. The U.S. Millennium Challenge Corporation's "good governance" eligibility standards provide a well-developed method of initial assessment.

Projections of climate catastrophe seem unlikely, given the UN's finding that there have been no statistically significant changes in extreme weather variables to date in the era of CO_2-based fear. Still, even assuming that alarming projections are correct, the near-term benefits of low-cost coal electricity to African economic opportunity and life expectancy far outweigh its modeled impact. Even under the most optimistic growth scenarios, Africa would account for less than three percent of total world emissions of CO_2.

The United States should assist Africa in its electrification with the most reliable and affordable methods African governments choose. Any other policy would be a life-threatening return to colonialism – carbon colonialism.

I. Electricity Poverty and Indoor Air Pollution

China and Sub-Saharan Africa had the same life expectancy in 1960: 44 years. Today, China is at 77, near the U.S. figure of 79, while Africa has only risen to 61.[1] For today's one billion Sub-Saharan Africans, this represents a loss of 16 billion years of life for not keeping pace with China.

The story is even more shocking for average personal income. In China, per-capita income (adjusted for inflation so that a dollar reflects the same purchasing power in both eras) rose from $223 in 1960 to $9,628 today, an annual growth rate of 6.6 percent. In Sub-Saharan Africa, income started out much higher, at $1,305, yet rose at only an annual rate of .7 percent to $1,972.[2]

A better measure of a region's poverty than average income is the percentage of people living in absolute poverty, which is defined by the World Bank as an income of less than $1.90 per day. In East Asia, 55 percent of people were absolutely poor in 1990, but only 2 percent are today. In Africa, the percentage fell only from 61 to 41 in the same period.[3]

Why the difference? There is no easy answer, given the tremendous historical differences between these regions. However, on the timelines for all these variables one can see that Africa experienced a horrific lost two decades between 1980 and 2000 during a perfect storm of the effects of economic strain in European trading partners, a proliferation of ethnic and religious civil wars, corruption, weak governmental control, a collapse in mineral and commodity prices, and the HIV/AIDS crisis that devastated Southern Africa and had considerable impact throughout the continent.[4] Conversely, the strong recovery since 2000 appears to be driven by high export demand and higher prices for minerals and other commodities, progress in treating AIDS and limiting the transmission of HIV, increased child immunization programs, and a dramatically reduced number of civil wars.[5]

Low access to electricity is one of the key causes of Africa's high poverty levels. The primary reason for this is that economic growth in a competitive, global market requires reliable, universal electrification. A secondary reason is that, according to the World Health Organization (WHO), indoor air pollution is one of the world's greatest environmental health risks.

Globally, WHO estimates that three billion people cook, heat, and light inside their homes with solid fuels – wood, charcoal, and dried animal dung. The poisons and particulate matter from burning solid fuels kill almost four million people a year from pneumonia (27%), heart disease (27%), pulmonary

disease (20%), stroke (18%), lung cancer (7%), and a variety of impaired immunities. Half of pneumonia deaths in children under five are from soot in the house.[6]

WHO estimates the African share of these annual indoor pollution deaths at 439,000.[7] Dangerous levels of indoor air pollution are almost guaranteed for families without access to electricity. UNICEF reports that 352 million Africa children live in homes with solid-fuel cooking.[8] One leading researcher told the WHO: "Having an open fire in your kitchen is like burning 400 cigarettes an hour."[9]

Of the one billion people in the world without access to electricity, the majority are in Africa.[10] Nearly all businesses suffer from unpredictable rationing via "brownouts" and even blackouts. Only 43 percent of African households are classified by the World Bank as having access to electricity, half of the global rate. In comparison, China now has reached 100 percent. For rural African households, the figure is only 25 percent.[11]

These estimates clearly overcount reliable access in Africa: more than half of surveyed "access" households in Africa suffer multiple blackouts each week.[12] Given the higher number of children in poorer families, it is more reasonable to accept the estimate by U.S. Power Africa that only about a third of Africans have access to reliable electricity.[13] Power Africa further estimates that 600 million people will still lack coverage in 2040, and that rural access will, under current policies, rise to only 40 percent. Millions of women and children would continue to walk many miles a day to gather not just water but wood for indoor burning, adding to deforestation.

The World Bank explains that because poverty causes low consumption and payments, electricity in Africa is far more expensive than in the far wealthier United States: "Currently, the unit cost of electricity to consumers in many countries in Africa is more than double the cost in high-income nations such as the United States (US$0.12/kWh) … In many African countries, it would cost more than 10 percent of per capita GDP to power a refrigerator for a year, a far larger share of most households' income, considering income inequality."[14] Clearly, universal electricity is one of Africa's most pressing human needs.

II. Electricity Generation and Outdoor Air Pollution

As African governments seek to increase access to electricity to tackle the continent's life expectancy shortfall, there is a risk that a coal-fired solution that reduces the indoor air pollution problem might also aggravate the outdoor air pollution problem. However, there is certainly one important way in which any broader and better grid would help in the fight against outdoor air pollution: it would end the "dieselization" of Africa in recent decades, as demand for electricity has outstripped supply.

In factories, businesses, government buildings, and wealthy neighborhoods in every African country, a cacaphonous symphony of soot-spewing backup diesel engines erupts when the grid goes down, which is usually every day. CO2 Coalition staff have witnessed the perverse results of an unreliable grid all over the continent:

- In Sudan, despite the generation of 30 percent of electricity from dams on the Nile, diesel pumps run constantly to lift river water for irrigation, even at the confluence of the Blue and White Niles in Khartoum.
- In Nigeria, hotels ban guests from jogging because of the danger of breathing in the soot from their diesel backups, which kick in every few hours as the neighborhood goes dark.
- In Southern Africa, construction sites often don't even bother hooking up to the grid. To avoid blackouts they simply acquire and line up multiple generators and run them all day, filling the nearby streets with a noxious cloud.
- In universities throughout the continent, the size of the diesel engine goes up and the temperature of the office goes down as the status of the user rises. Students sit in stifling classrooms, professors get a fan in their office, department chairs get an old air conditioning window unit, and the president sits in meat-locker conditions as a dedicated industrial-scale diesel hammers away outside, drowning out conversation.

According to the World Bank's International Finance Corporation, in many African countries there is more spending on dirty backup power than on the electricity grid itself. In West Africa, backup kilowatts equal 40 percent of grid kilowatts.[15]

Still, even with the health benefits of ending dieselization, emissions of the pollutants sulfur dioxide, nitrogen oxides, and particulate matter like soot from the coal-fired component of the expected generation of additional grid power could also add illness and mortality from outdoor air pollution. This was certainly the case in China's dramatic 30-year transition to a functioning energy economy.[16] China has recently developed modern scrubbing technology for its new plants and as "retrofits" for old plants. Over 80 percent of all plants in China now have scrubbers, versus none, at present, in Africa.[17] However, many experts report that plant operators often turn them off to save money, power, and staffing.[18]

How big is the health problem of outdoor air pollution? According to WHO, globally it is just as big a problem as indoor air pollution, at four million deaths per year.[19] So far, Africa's weak electricity generation has kept its outdoor annual death toll (258,000) lower than its indoor one (439,000).[20] However, the outdoor toll is rising, from 164,000 in 1990, as generation increases, and will continue to rise if additional power is not provided in a cleaner fashion.[21]

It would obviously be preferable to add electricity in a way that dramatically reduces the pollutants that coal plants emit. However, even increasing African electricity without improving pollution controls would save African lives. Typical of "climate change" research that focuses only on one side of cost-benefit analysis, a 2020 paper by Lelieveld *et al*. concluded that eliminating fossil fuels would add one year to global life expectancy.[22] This analysis ignores deaths from indoor air pollution, and the fact that if fossil fuels were banned, far more expensive, far less reliable wind and solar grids would be needed to meet even current demand. That would raise prices and reduce exports and economic growth, and life expectancy is strongly influenced by economic growth.

Complete reliance on intermittent wind and solar energy would increase brownouts and black-outs and back-up "dieselization" in unreliable grids like Africa's. Without ready fossil-fueled backup power, the grids would collapse daily, at great cost to restart and repair. Finally, because the mining, refining, construction, and transportation of wind blades, solar panels, and batteries are so fossil-fuel intensive, wind and solar power generation would add the very pollutants to the atmosphere that a ban on fossil fuels is intended to eliminate. In this sense, there is nothing renewable about "renewable" energy.

Africa's Electricity Mix, Present and Future

Africa is projected to double its electricity capacity in the next 20 years. At present Sub-Saharan Africa uses 372 billion kilowatt-hours of electricity for its one billion people. For comparison, the United States has a consumption rate that is 34 times higher per capita, with 4.118 trillion kilowatt-hours being shared by 330 million people. South Africa accounts for 58 percent of Sub-Saharan consumption, versus only 20 percent of Sub-Saharan income.[23]

Countries in Central and Northeastern Africa that have major rivers, particularly the Congo and the Nile, primarily use hydropower for electricity. West Africa's electricity comes primarily from abundant oil, diesel, and recently gas-fired generation. Egypt and Ghana, among others, have added significant natural gas electricity to their mix.

Electricity from new natural gas finds and new and existing oil fields are expected to be part of the solution, but the infrastructure for moving gas and oil to power plants is in most countries quite costly to build and maintain.[24] Most gas pipelines in Africa today carry gas from its source to export terminals on the coasts, and so are funded by foreign corporations.

If it lacks a viable steel industry, an African country would have to import steel for fabrication into domestic pipelines or import the expensive finished pipe itself. An alternative might be the construction of gas-fired electrical generation and various manufacturing plants at the gas field. Transmitting energy through wires may be easier than moving the gas.

African natural gas production is expected to double from 2018 to 2040 to 250,000 MTOE (million tonnes oil equivalent, a tonne being 1,000 kilograms, or 2200 pounds), and oil production to double to 300,000 MTOE.[25] Most of the gas and oil, though, will continue to be exported to earn foreign exchange. Hydropower will quadruple, but only to about 30,000 MTOE, and nuclear power will remain stable at around 7,000 MTOE.

The so-called renewables – primarily wind and solar – are predicted to soar from virtually nothing today to match coal at 125,000 MTOE in 2040. However, at present, renewables are not mature or reliable enough to provide significant grid electricity in Africa. Major technological advances and cost reductions in generation and storage of wind and solar power will be required for this prediction to be realized.

Tragically, the amount of African energy coming from solid fuels like wood and dung is also expected to rise by 2040, although falling from a half to a third of total energy. If clean-coal electricity were to be promoted rather than restricted by developed countries' policies in Africa, it would take an even bigger bite out of solid fuels and indoor air pollution.

The continent's total electricity production, like consumption, is also dominated by South Africa, where 93 percent of power is coal-fired.[26] As a result, 90 percent of all of Africa's fossil-fueled electricity comes from coal. Only two countries in Sub-Saharan Africa use more than 5 billion kilowatt-hours of fossil-fueled power: Nigeria at 25 billion kilowatt-hours and South Africa at 220.[27] In North Africa, Morocco has a well-developed coal-fired grid, with coal imported from South Africa and Poland.

Via a regional grid, South Africa also supplies power to its six neighboring countries as well as Zambia and the Democratic Republic of Congo. At times, South Africa also imports power from this grid. Mozambique and Botswana, which are on this grid, have major new coal developments that will contribute additional power to the grid.[28]

While South Africa produces 90 percent of African coal today (and exports a quarter of it), it has only 69 percent of all African coal reserves, and is expected to account for only 75 percent of African coal in 2040.[29] The remainder will come from substantial untapped coal deposits in and around Tanzania in East Africa, and in the Sahel region of West Africa.[30]

South Africa has another interesting use for coal. It has long led the world in synthetic fuels – gasoline, diesel, and other oils made with coal liquefication. South Africa produces about 58 million barrels per year, accounting for 23 percent of its oil consumption.[31] China is the only other major producer, at 39 million barrels per year.[32]

Power analysts agree that Africa's cheap, abundant coal, which is easy to transport, is going to be used on a large scale for electricity. Despite political and economic pressures on the use of coal, its share of total world energy increased steadily from 24.5 percent in 1973 to 26.9 in 2018.[33] Most of that coal was used for electricity; about 12 percent was used for producing steel.[34]

African production of coal for power is expected – under current policies in which developed countries are blocking financing for coal-fired power plants – to hold steady through 2040, at about 125,000 MTOE. This will require dozens of new power plants to replace old ones ending service.

Global Energy Monitor counts more than 100 coal-generation plants being planned in 11 African countries other than South Africa. Their power would total eight times the current continental generation from coal. China is expected to finance and construct half of the new plants.[35] Without modern scrubbing technology, Africa could be trading the indoor health crisis for an outdoor one.

III. U.S. Policy Toward African Coal-Powered Electricity

Africa has a deadly health problem arising from an electricity crisis of low access and high cost. As a matter of national policy, the United States Government is committed to helping solve this problem, both bilaterally through the Agency for International Development's Power Africa program, the Export-Import Bank (EXIM), and the Overseas Private Investment Corporation (OPIC), and multilaterally through its financial contribution and policy votes at the World Bank and the African Development Bank and Fund (AfDB).

The World Bank approves new projects totaling about $15 billion annually in Sub-Saharan Africa, out of its $45 billion global total. In return for its typical annual contribution of about $1.2 billion, the United States has a veto-level 17 percent of the Bank's voting power.[36] The AfDB lends about $7 billion annually, and the United States, while a major funder with about $240 million in annual donations, has only about seven percent of voting power.

Power Africa receives $70 million annually in U.S. Government funding,[37] and uses it to provide technical support and coordination to AID, other U.S. agencies, and international donors who carry out their own energy projects.[38] The EXIM Bank provides low-interest loans to American exporters and OPIC provides investment insurance to American corporations, and both have energy projects in Africa in their portfolios.

How has the U.S. commitment to expanding access to electricity in Africa fared? Despite pressure from both governments and "Green" groups in developed countries, through the mid-2010's, African governments were able to prevail upon the World Bank to keep backing already-existing coal-fired projects, and upon the African Development to back new ones. Their position was explained by such leaders as AfDB president Donald Kaberuka, former UN Secretary-General Kofi Annan, and South African Mineral and Energy Resources Minister Samson Gwede Mantashe.

In 2015 Kaberuka said, of pressure from developed countries to ban African coal power: "It is hypocritical for western governments who have funded their industrialisation using fossil fuels, providing their citizens with enough power, to say to African countries, 'You cannot develop dams, you cannot develop coal, just rely on these very expensive renewables.'… African countries will not listen."[39]

Discussing his Africa Progress Panel's "Lights, Power, Action" report in 2017, Annan said: "As our report clearly states, the costs of transitioning to renewables may be prohibitively high in the short term – especially for countries that use their sizeable endowments of coal and other fossil fuels to generate energy. What we are advocating is that African governments harness every available energy option."[40]

In 2019 Mantashe said: "They even want to tell us to switch off all the coal-generated power stations… until you tell them, 'you know we can do that, but you'll breathe fresh air in the darkness'…. As much as we intend to utilise the sun and wind resources we have, we intend to continue to use our fossil fuel resources, and to increase investment in ... clean coal technologies…. We want to supply energy at a cost-effective level because if it is too expensive I can tell you that it becomes a 'nice to have' but people do not access it."[41]

But by 2019 both funders had given in to the demands of their Western donor governments. The World Bank had provided no direct lending to new coal-fired projects since 2010,[42] and in 2013 it adopted a formal policy to bar such lending, except where no feasible alternative was possible.[43] Now it has even shut off lending to maintain projects that are already operating. It actually lends to help countries close coal mines and replace coal-fired plants.[44] In effect, the World Bank's response to the problem of indoor air pollution is to ignore the simple solution of electric stoves, and instead back the trendy efforts by Western NGO's to supply better cook stoves.[45]

This minimalist and unnecessary solution often turns out to be no solution at all. The results of a large, randomized trial, to its authors surprise, "were unfortunately discouraging: through four years of follow-up, we found that the stoves did not lead to long-run improvements in health and fuel use remained unchanged."[46]

The African Development Bank, under new president Akinwumi Adesina, announced an end to new coal projects, saying that, "Coal is the past, and renewable energy is the future…There's a reason God gave Africa sunlight."[47]

When World Bank President Jim Kim rejected the Bank's final coal-fired proposal in 2018, for Kosovo, he justified his decision by finding that its electricity would have been more expensive than if it came from intermittent solar and wind and was stored in batteries.[48] But these sources are generally far more expensive than fossil-fueled power – four times as much, in the United States – when subsidies and the necessary backup power are factored in.[49] The confidential World Bank study only achieved Kim's result by assuming better performance from batteries than has been achieved, adding "externalities" to the coal project like health costs, without considering the health benefits of affordable and constant power, and economically penalizing the proposed coal plant for wasting the "excess" energy that could be generated from existing, dirtier coal plants.[50]

Both banks will continue to support the addition of scrubbing technology at coal-power plants, like the giant Medupi plant in South Africa. During its push for the World Bank loan it eventually received, despite the Obama administration's abstention on the vote, the South African parastatal Eskom had pledged to add scrubbing early in its operation. However, after ten years this step is still in the planning stage.[51] In addition, the banks continue to loan for the boom in Africa of natural gas projects, pipelines for gas and oil exports, and transmission lines for electricity from any source. "Green" groups are targeting all of these as next steps in their campaign to ban all fossil fuels.[52]

Initiated by the Obama administration, Power Africa never funded coal projects. Instead it focuses, in order, on natural gas, wind, solar, and hydro.[53] Under the Trump administration, despite the creation of a Clean Coal Initiative at the Energy Department, the suspension of the anti-fossil fuel "Clean Power Plan," and departure from the Paris Climate Agreement, no effort was made to reverse the Power Africa, World Bank, and AfDB decisions to get out of coal power for electricity.

IV. American Clean Coal Technology: The Turk Plant

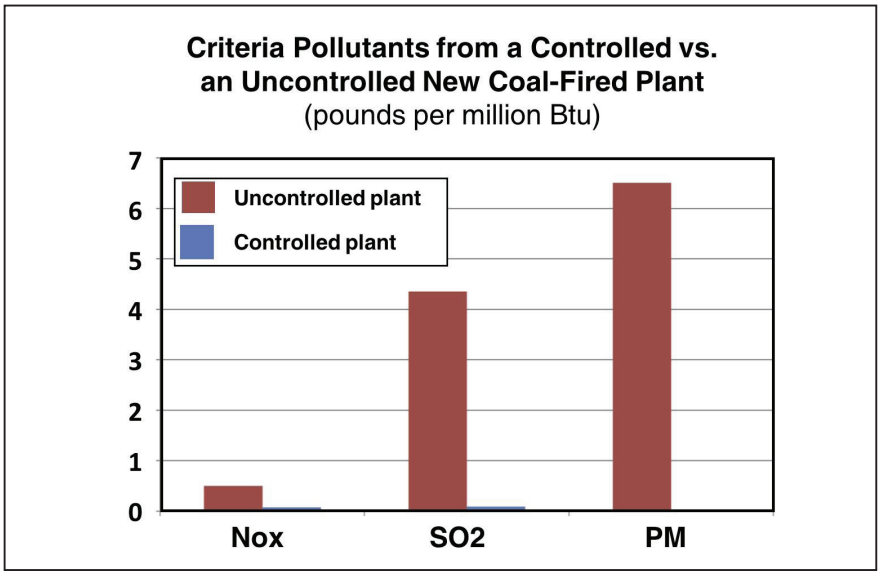
American firms have developed much of the "new-tech" ultra super-critical (USC) coal-fired technology that is now being used around the world.[54] USC refers to the higher steam temperature and pressure achieved from metallurgical improvements in boilers over the "critical" temperature and density at which a liquid becomes a gas. For water, that is 647 Kelvin at 221 bar. This increases the efficiency of the power, so less coal is required to produce the same amount of energy.[55]

A USC plant uses a variety of pollution controls to reduce air pollution. This is known as High Efficiency Low Emission (HELE) design. Here, too, American firms have developed new technologies, so that 97 percent of pollutants are removed and some can actually be turned into useful commercial products, like construction materials.[56] By fine-tuning the air quality systems of new-tech power plants, pollution controls can achieve reductions of up to 99.9 percent.

Coal is rarely refined like other carbon-based fuels. It is usually burned as-is. As a result, if not fitted with systems to capture the noxious gases that result from burning the impurities found in natural coal, those impurities are released to the atmosphere. The main pollutants are sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM) such as soot. The Environmental Protection Agency defines these – along with ground ozone, carbon monoxide, and various compounds of lead – as "criteria pollutants." Carbon dioxide, a mild warming gas that is also emitted by the conversion of coal to power, is not harmful to people or the environment, so it is not regulated as a criteria pollutant. In fact, because CO_2 is a potent plant and plankton food, emissions from human activity have raised global plant productivity by about a third.[57]

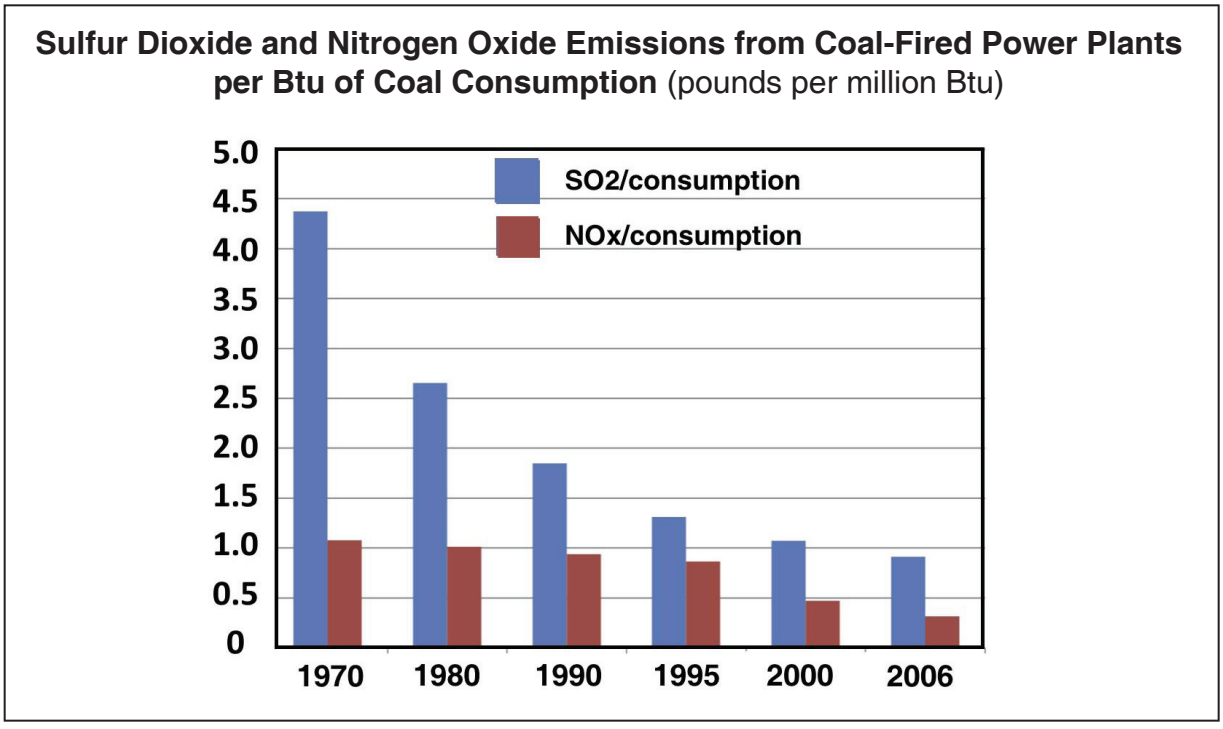
The levels of criteria pollutants from a coal plant burning a typical supply of coal are shown by the tall columns in Figure 1 for the three major pollutants. To the right of the tall columns, much shorter ones indicate the levels of emissions for a coal plant fitted with effective controls. The numbers on the vertical axis are pounds generated per million British Thermal Units (BTUs) of energy. PM is reduced from 6.5 pounds to 0.013, essentially zero. SO_2's 4.4 pounds is reduced to 0.085, and the 0.5 pounds of NO_x to 0.07 pounds.

Figure 1, drawn from Department of Energy data, was published in 2008, 12 years ago. Since then, the technology to reduce emissions has continued to improve. Very importantly, the technological advances have also reduced the cost and complexity of the control systems. The historical trend to limit criteria pollution from coal plants is revealed in Figure 2.



Source: National Energy Technology Laboratory, Cost and Performance Baseline for Fossil Energy Plants, DOE/NETL-2007/1281.

Figure 1



Source: Energy Information Administration, Annual Energy Review 2007, and Environmental Protection Agency, National Air Pollutant Emission Trends, 1990-1994, EPA-454/R-95-011, October 1995

Figure 2

Figure 2 shows that from 1970 to 2006, emissions from coal plants in the United States fell sharply. This is particularly impressive because it has primarily been the result of fitting older plants with new air quality control systems. New plants today would be far more effective, being specifically designed to work better with advanced control systems. Due to the tremendous variability among installed electrical generation and manufacturing systems, retrofitting falls beyond the scope of this paper. However, it may have some applications in improving air quality in the African context.

CO2 Coalition Members and staff visited the fully-controlled John W. Turk Jr. power plant in Fulton, Arkansas, and interviewed personnel at length. When it came on-line in 2012 it was the first HELE plant built in America. The collapse of the price of natural gas due to "fracking" has also made it the only one built, as new coal plants became uncompetitive. Here are the details gleaned from the visit and interviews.

Turk was built and is operated by American Electric Power. It is a latest-generation ultra super-critical 600 megawatt coal-fired power plant serving Arkansas, Texas, and Oklahoma. Its higher efficiency than the 1970's designs of most existing U.S. plants comes from higher steam temperature and pressure permitted in its boilers by advances in metallurgy and welding. There was no single magic bullet in its technology, but rather just continuous testing and modification.

The benefits of USC boilers are not just more electricity, but, because there is less coal burned for a unit of power produced, also smaller equipment on site and less exhaust flue gas. Down-stream benefits include less materials for smaller containment vessels, and reduced waste, re-agents, landfill, and ash.

The composition of coals can vary significantly. Turk uses low-sulfur coal, delivered by rail from Wyoming's Powder River Basin. The plant and its equipment are specifically designed for this particular type of coal, for which AEP has long-term contracts to last the life of the plant. Putting in different coal, outside of a narrow range of chemistry, is not practical – it would create operational challenges and possibly damage equipment.

The boiler materials are the same as in older plants. The steel used is a blend alloy of iron and other minerals. Minute changes in the blend affect crystalline structure and hence permit higher temperatures, improving performance. The boiler is made primarily from American materials, and is fabricated as much as possible at the factory. Sophisticated welding takes place at the plant, putting together pieces to make boilers and containers. An assembled boiler could not be transported, because it is so huge – the Statue of Liberty would fit inside. A large number of specialized workers were needed on-site for the 18-24 month construction cycle. Turk was more expensive than an older plant, at $1.8 billion, but its increased production has already paid off the difference.

Natural gas was $10-15/thousand BTUs when the plant was approved, but now it is at $2-3. So it has not made economic sense to build more of these plants in the United States. In addition, improved efficiency, LED lights, and low population growth have resulted in only a modest increase in American demand. Hence, forecasts aren't showing a need to increase load in the United States.

High-school graduates, trained by AEP, comprise the vast majority of workers at the Turk plant. Some engineers are in plant leadership, but it's this skilled labor that runs Turk. Servicing every two years shuts the plant for a month of off-line work on inspection, wear, and replacement. Problems in between full servicings include steel boiler leaks, welding, and replacing parts.

It takes perhaps three to five percent of the plant's energy to run the pollution controls, and a high cost re-agent, limestone, is needed for the scrubber. However, these costs can be balanced by sales and uses of the waste. Federal and state emissions and efficiency standards are enforced by continuous monitoring. The readings are provided to regulators so they can certify the equipment. And "you can see or smell" most of the pollutants, so the local community would know too if the pollution control systems were not working properly.

Figure 3 is a schematic of an uncontrolled coal power plant where air quality control systems to limit emissions of post-combustion byproducts have not been installed.[58]

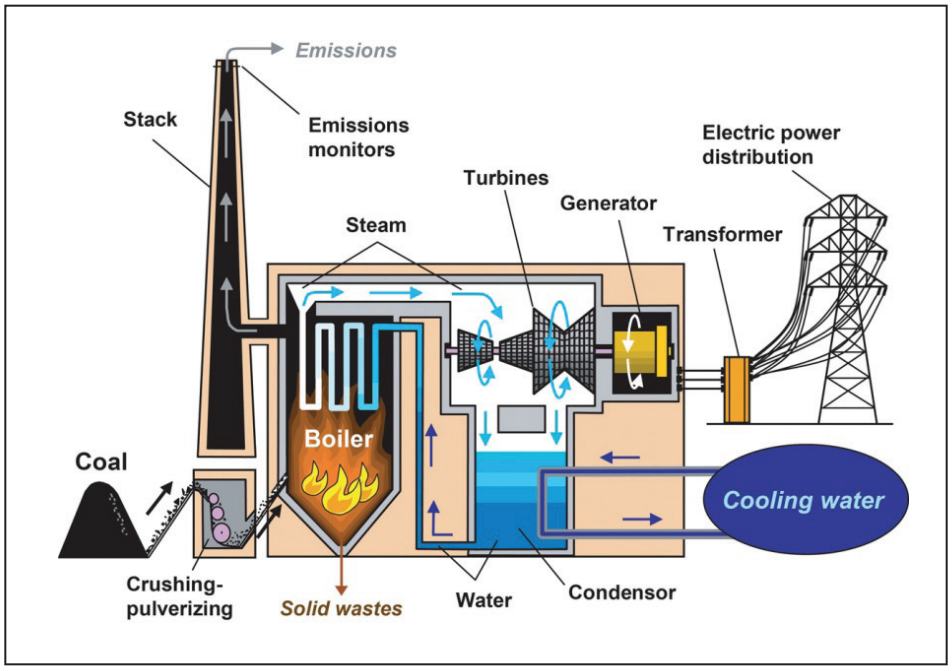


Figure 3

Figure 4 is a schematic of a controlled coal power plant like Turk, incorporating its three sequential air quality systems: Selective Catalytic Reduction (SCR) of Nitrogen Oxides, an Electrostatic Precipitator (ESP) to remove Particulate Matter such as soot, and Flue Gas Desulfurization (FGD) to reduce Sulfur Dioxide.

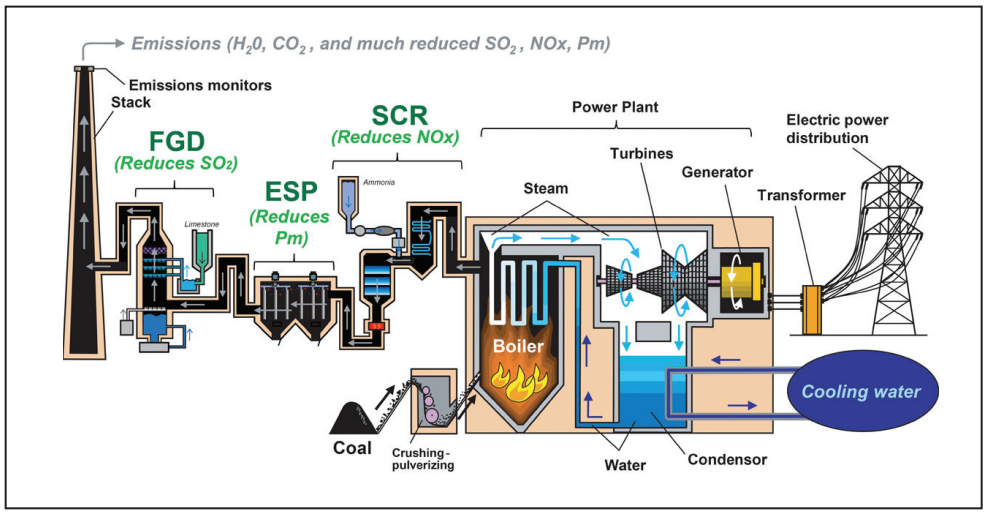


Figure 4

Selective Catalytic Reduction

Using a mix of ammonia gas (NH_3) and various catalysts, nitrogen oxides (NO_x) are converted to nitrogen gas (N) and water (H_2O), as with the catalytic converters installed in automobiles. Continual improvements in technology make SCR systems less expensive and more efficient, resulting in the removal of essentially all NO_x. SCR takes place at high temperature, right after combustion, in a huge box. It operates like a large-scale catalytic converter from a diesel vehicle. Its vanadium metal alloy converts the pollutant, after anhydrous ammonia or urea turns NO_x into N_2 and water. The now nearly pollution-free gas is eventually vented. The technology for the catalyst is sophisticated and proprietary.

Electrostatic Precipitator

An Electrostatic Precipitator (ESP) (Figure 5) collects fine particulate matter found in coal combustion exhaust, by means of static electricity. ESP gets the flue gas at a lower temperature after SCR. It, too, is essentially a huge box, which lowers the velocity of the gas moving through the system. A series of steel plates with wires dangling down have an electric charge, which creates a static electric field. Fly ash collects on the plates. Hammers strike the plates, and cakes of ash fall. Almost all the fly ash is sold as a cement substitute for concrete. Concrete replacement is becoming even more valuable as coal plants shut down.

Improvements in the design and engineering of precipitators have lowered costs, thereby improving collection capacity and efficiency. An alternate technology uses “baghouse” filters, big socks that catch the small particles even more efficiently. They are higher maintenance, though – a hole in a sock needs repair.

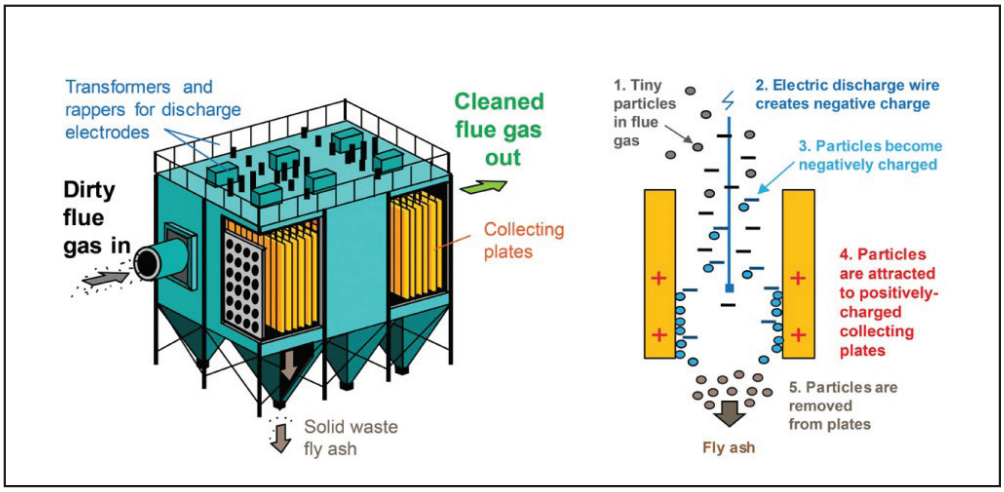


Figure 5

Flue Gas Desulfurization

Known to the general public as "scrubbers," Flue Gas Desulfurization (FGD) units (Figure 6) utilize different agents to break down SO_2, a byproduct of combustion, and convert it to other byproducts which can then be captured. Scrubbers are complex, costly pieces of equipment, but as with other air quality systems, innovation and technology are lowering operating costs, thus improving efficiency. FGD operates at a lower temperature (below the boiling point of water) and uses wet chemistry to create a mix of high sulfur, SO_2, sulfuric acid, and water. The gas is slowed again in another big box, and water and limestone are added to create calcium carbonate. The reaction creates a couple percent more of harmless CO_2 and leaves gypsum behind that is sold to nearby wallboard manufacturers.

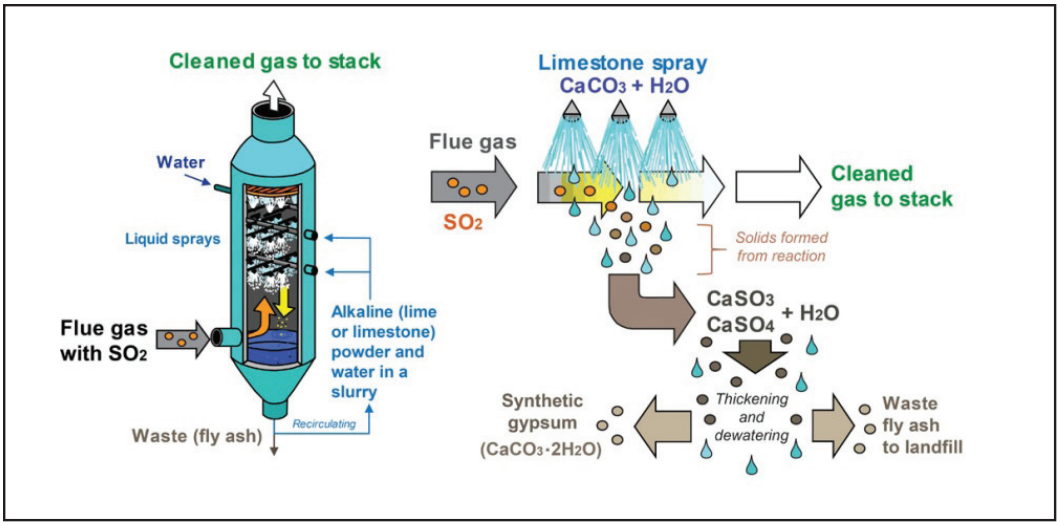


Figure 6

Mercury and Toxic Air Standards

The Environmental Protection Agency regulates Mercury and Toxic Air Standards (MATS). Mercury is the main toxic trace element found in coal. All three of the air quality systems described above contribute to removing mercury and other toxic elements from the exhaust stream. Other systems, such as activated carbon, fabric filters and bromine additives, can improve mercury reduction from different grades of coal.[59]

Water for the Plant

Coal plants deliver power from steam turbines, and for steam, you need water. Turk can draw up to 6,500 gallons of water per minute from the Little River, although it usually uses less. The river was dammed by the Army Corps of Engineers, and the Turk plant draws amounts to a quarter of one percent of the river's flow. Rainwater and recycled water are also gathered in ponds at the plant. Water is used in the boiler, where it is heated into steam, and in the cooling towers that convert that steam back into heated "boiler make-up water" for re-use. It is also used in one of the cleaning technologies, the scrubbing of SO_2 in FGD.

Before fresh water can be used at the plant, it must be treated through reverse osmosis. This removes impurities that might damage the equipment. The treatment process is less extensive than the process for power plants that supplement their fresh water with municipal wastewater, brackish ground water and seawater.

Eventually, re-used water gathers enough impurities to require storage in lined ponds. The plant is designed to handle 1,500 gallons of wastewater per minute, but rarely needs to handle that much. The solid pollutants settle at the bottom of the clay and synthetic-lined ponds, and are dredged up to be taken to landfills. The water can then be recycled back into use at the plant. Turk does not use water to remove fly ash, as was the case in older plants. Instead, the fly ash is preserved in dry form, and trucked to landfills.

V. Challenges in the African Policy Arena

Can this Turk-style, new-tech generation and cleaning of coal-fired electricity be successfully built and maintained in Africa? After all, the continent is littered with "White Elephants" – industrial, agriculture, and health projects that worked fine in the developed donor country but could not be sustained in Africa's political and economic framework. Below we discuss ten major issues that African governments and foreign donors and investors will need to consider.

Public vs. private ownership

Most grid electricity in Africa – 80 percent – is delivered by "parastatals" – essentially government companies.[60] This is the opposite of the situation in the United States, where 72 percent of grid electricity is delivered by regulated private companies.[61] The type of ownership has implications for the ability to plan, invest, price, and maintain power. The Turk plant, for example, required long-range investment and planning, and a near-certainty that regulators would continue to approve prices sufficient to provide a profit from the venture.

African governments would be bucking tradition to approve regulated corporate ownership of electricity generation and transmission, but they have done so in recent decades with state-owned enterprises in other spheres, such as mining, steel-making, food processing, infrastructure, textiles, telecommunications, and cement.[62] In addition, Nigeria sold 15 of its parastatal electricity companies in the 2010's.

It is not essential that new-tech coal generation in Africa be done by regulated corporations instead of parastatals, but it is certainly worth exploring in various settings. Probably the most powerful argument for private ownership is that it provides an incentive for long-term planning and investment. South Africa's parastatal energy giant, Eskom, had great success in the two decades after the advent of democracy in 1990 in achieving nearly universal electrification of urban zones. However, the government did not provide the long-term financing it needed to prepare for replacing equipment. By the mid-2010's South Africa began to experience power shortages, and today blackouts are a normal part of daily life.[63]

Limited access to foreign exchange for spare parts and service contracts

Due to their economic weakness versus the developed world, African governments typically protect their currencies through an official exchange rate. That means that they are not freely convertible on an open market, and that imports must be approved from a limited supply. Electricity companies without other sources of internationally-convertible currencies have to line up with other companies for permission to import.

This creates bottlenecks for the flow of equipment and experts needed to service and maintain complex, almost always foreign power equipment. A slight delay in fixing a transmission tower or a boiler can disrupt the entire grid in a national system that operates much closer to the supply edge than in developed countries. Governments can try creative approaches, like dedicated foreign bonds, to try to guarantee a supply of foreign exchange for the energy sector, but there are many other

sectors that want such a supply as well. For nations that export fossil fuels, such as Angola, Nigeria, the Sudan, and soon Uganda, the problem is less daunting. They have a ready and constant source of convertible currencies.

Foreign versus local workforce

Both parastatal and private energy companies will rightly try to maximize the use of nationals as workers. Many African institutions provide strong technical and engineering education, and many Africans receive additional education in these topics in developed countries. However, the "brain drain" of Africans deciding to pursue their careers outside the continent, particularly in medicine and commerce, is also at play in the energy sector. There is, of course, also a "brain circulation," in which Africans return to work at home after a period abroad.

A plant like Turk would have to be mostly constructed by foreign workers who have done similar work before. However, in its operation and maintenance, the Turk plant has found that nearly all the work can be done successfully by local workers who are trained at the plant. A small number of engineers and managers, either foreign or national, would also be required.

Weak monitoring and regulation

The framework for the regulation of emissions is older and more extensive in developed countries than in Africa, but the Turk regime can be easily imported along with the plant. The readings of pollutants takes place on site, and the computerized monitoring has been tried and tested in Arkansas.

The greater challenge will be for African governments to regulate the use of water for steam generation, cooling, and cleaning of pollutants, and then monitor the wastewater and solids left over from the cleaning process. While fresh water from rivers and lakes is the preferred source, the International Energy Agency reports that developing countries are starting to use more municipal waste water, brackish groundwater, sea-water, and desalinized water in their coal plants.[64] Pre-treatment of these sources is more extensive than for fresh water.

Corruption

As in all countries, power companies in Africa, and particularly parastatals, face a variety of distortions from corruption. These include: political demands for preferential services for certain areas; political demands for the hiring and retention of unnecessary and unqualified workers; and ongoing kick-back schemes that public officials, including in some cases all the way up to the president, promote with regulatory threats and protect from police investigation.

In some countries, such as Sudan, Uganda, Nigeria, and Equatorial Guinea, these well-documented abuses are so extensive and routine that they damage the national economy. South Africa, in particular, has suffered from political pressure to over-employ. Foreign companies will have to evaluate the risks of investing in such an uncertain environment.

Written agreements for independence and investigations will not in themselves avert such problems.

Companies should keep in mind such chilling examples as the World Bank's 2001 agreement with the government of Chad under dictator Idriss Deby. The Bank agreed to finance the exploration and pipeline export of oil, in return for the revenues being placed in a jointly-controlled "lockbox" to be used only for poverty programs. Once the construction was done and the oil was flowing, Deby tried to confiscate the account for his security apparatus. After much back and forth, Bank president Paul Wolfowitz gave in and let him take the dedicated funds. In return, Deby agreed to repay the loan early from his other, now-massive oil revenues.[65]

Inability to charge customers

In most African countries, consumers receive electricity at well below true cost. Indeed, in only two of 39 countries studied in depth by the World Bank were the providers "fully recovering their operational and capital costs."[66] Connection fees are often too high for single households to pay, so a number of households will agree to draw from the same meter. In Ethiopia, for example, there are two and half times as many grid homes as meters. This practice, however, makes poor users ineligible for subsidized "life line" rates.

Throughout the continent, attempts to raise electricity rates lead to controversy and protest, especially when they come during blackouts caused, at least in part, by insufficient revenue. Governments often back down from rate increases. The World Bank recommends targeting subsidies on poorer households, but such differentiated approaches can be difficult to sustain politically.[67]

Theft of services and materials from transmission lines

In addition to sharing hookups, in some countries there is a large-scale tradition of simply bleeding power off overhead transmission lines. In this case, the necessary revenues for the power are completely lost to the company. A strong police presence would be needed to interrupt the practice and then, over time, prevent it.

Similarly, African transmission lines are often targeted for theft because of the scrap value of the copper, steel, and other materials in the lines and even the pylons. In South Africa, the thefts cost half a billion dollars per year.[68]

Political instability

For a variety of historical reasons – some relating to colonial powers forcing the combination of distinct national groups into single countries, some relating to the economic stress of Africa's status in the global economy – Africa has had a politically volatile 60 years since independence. Most countries have either experienced civil wars, election violence, coups, and military political power, and nearly all the rest have at times been destabilized by the resulting flow of refugees and drop in commerce.

In this context, how reliable will a 40-year agreement to buy coal from a particular set of mines be? As noted, new-tech coal plants are built to handle a specific type of coal, within a narrow chemical range. In addition for plants that are not built near the mine, and rely on transportation by rail, truck, or barge from another national region or country, political instability could be a major risk.

Failure to pay workers and managers

One of Africa's enduring problems is the inability of governments to pay their workers and managers promptly and fully. Budget shortfalls are a regular feature of life in most countries. Workers in government enterprises – at hospitals, doctors as well as orderlies; at universities, professors as well as cleaners – frequently strike after gaps in pay stretch into months.

Parastatal energy companies try to segregate their operating revenues from other government revenues, but that is more difficult for their capital budgets. In both cases, extreme and even typical distress in government finances is certain to complicate their ability to pay staff.

Weak police and judicial systems

Many of the challenges outlined above require companies to rely on functioning police and judicial systems that cannot be arbitrarily deterred by powerful politicians. Some countries have set up units of anti-corruption financial forensic specialists, like South Africa's now-disbanded "Scorpions." But police and prosecutors are among the government workers affected by low and intermittent pay. At times some of them, too, demand corrupt payments from citizens.

A number of non-governmental watchdogs, both African and international, study and rate African countries on corruption and the state response. While there appear to be few technical reasons why new-tech coal cannot work in Africa, companies will have to assess the judicial environment as well as the political and economic one when making their decisions.

* * *

Our research question for this White Paper has been whether American new-tech coal-fired electricity generation can improve life and life expectancy in the African context. Reviewing these ten areas of challenge, the answer must be a carefully qualified "yes."

American companies should explore the African landscape, but seek to structure agreements that minimize the very real risks outlined above. In an attempt to address "good governance" issues such as the judicial system, corruption, and public accountability, the Millennium Challenge Corporation was established in 2004 to provide U.S. foreign aid only to governments with a positive track record and a promising future record. It has developed a detailed assessment method, which could provide a starting point for decisions about financing a HELE plant.[69]

U.S. loan and investment guarantees arranged by the EXIM bank, OPIC, and Power Africa would play a crucial role in successful projects. That is why the first order of business must be for U.S. policy at the World Bank, African Development Bank, and Power Africa to stop opposing coal plants in Africa, and start aiding African governments that choose to use all of the continent's available resources to provide clean electricity, indoors and out.

Africans have the human right to the electricity they so desperately need. After all, when it comes to the improvement in health that universal electrification will bring, African Lives Matter.

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