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Executive Summary

With its focus on reducing environmental impacts, the energy transition is forcing an examination of the role of coal-based power plants. The rapid addition of new coal-based generation capacity from FY2011 to FY2016 resulted in excess power generation capacity nation-wide. Currently, there is more than enough firm generation capacity to meet the peak demand. With the volume of new capacity in the pipeline, this situation of excess could last for several years. Questions are being asked about whether the older, and often more inefficient, plants should be retired. Decisions about coal plants need to take into account two additional issues. The first is the requirement for emission control systems (ECS) to reduce emissions of oxides of sulphur (SOx) and oxides of nitrogen (NOx) as per norms announced by the Government of India in 2015. The second issue involves making coal power plants more flexible to compensate for the varying and intermittent nature of renewable energy (RE). It is often preferable to operate older plants, which usually use sub-critical technology, in a flexible mode.

These three issues—retirement of older coal plants, installation of ECS, and making plants more flexible—are currently being addressed separately, based on simple uniform rules. For example, some experts suggest coal plants older than 25 years should be retired while others suggest those older than 20 years be retired. Requirements for ECS are uniform, except that they are separated into two categories by the plant's size and three by the plant's age. There are no distinctions for either expected Plant Load Factor (PLF) or location of plant. Discussions about increasing flexibility have started recently and there are no specific rules or regulations yet.

However, these three issues are interlinked. Smaller, subcritical plants are more suitable for flexible operations. Older plants with very low fixed costs can operate at low PLFs without much of an impact on the cost of electricity from those plants. Hence, instead of devising uniform rules to address these issues, a more strategic approach may yield better outcomes. For example, instead of a uniform requirement for ECS, it may be better to use a phased approach, where areas with high load factors, high pollution levels and a larger population exposure to emissions get higher priority, and, perhaps, even more stringent norms. This should not be seen as a weakening of environmental protection. Instead, for the same expenditure, there will be greater protection from emissions. This discussion note suggests an integrated approach to address the three issues, based on a long-term system-wide analysis that considers costs, environmental impacts, and need for flexibility.

Introduction

The energy transition has increased the share of RE in the generation of electricity, resulting in a decreasing share of coal. Due to the rapid growth of new coal capacity nation-wide over the period 2011-2016, there is excess generating capacity in India. The demand, at the grid level, reached a peak of 183 GW on December 30, 2020 (Sahai, 2020). As of November 30, 2020, firm generating capacity, which excludes RE,[1] stands at about 284 GW. Even if we exclude the 25 GW of gas-based power, because of uncertainty of supply, there is firm capacity of 259 GW.

However, this is gross capacity. If we factor in auxiliary consumption (which gives us net delivered or busbar production) and inter-state transmission losses, to get to 'grid demand', we lose about 10 percent. On top of this, some capacity is always down for maintenance, both planned and unplanned. There are also outages for other reasons such as issues with fuel supply. Thus, currently, there is sufficient generating capacity to meet peak demand but not nearly as much as one might think. As of October 2020, 60 GW of coal capacity was under construction (CEA, 2020a). There is a lot of uncertainty about the status of many of these power plants in the pipeline. It is difficult to ascertain when they are likely to be commissioned and it is unlikely that all of this new capacity will be brought on-line. In spite of this uncertainty, on a nation-wide basis, for several years, there is likely to be more firm generation capacity than needed to meet peak demand.

This excess capacity has been a driver for a flurry of studies and commentary recommending that older coal plants be retired. Current prices of electricity generated from additional RE are lower than electricity prices from many coal-based plants, especially ones that are far from the coal mines and incur high transportation costs. Thus, at first glance, retirement of older plants seems like a reasonable suggestion. However, one MW of RE capacity is not equivalent to one MW of coal capacity. This is because RE is intermittent and available for only part of the day. Also, the PLF of RE is usually about one-third of the level for which coal plants are designed. If old coal plants are retired, new non-RE capacity or storage will also be required to replace the older coal plants. This will be more pronounced for the evening peak hours, when RE contribution is likely to fall to very low levels.

[1] Data from http://carbontracker.in show that RE's contribution to the evening peak can fall to a few percent on many days of the year.

The issue of retiring old plants should be considered along with the costs of additional measures needed to adapt the remaining coal-based plants to meet new requirements. The first is the requirement for retrofitting remaining coal plants with ECS to reduce emissions, especially of oxides of sulphur (SOx) and oxides of nitrogen (NOx). The second is the need to make some of the remaining coal plants more flexible in their operations to compensate for the variability and intermittency of RE and maintain the reliability of the grid. Depending on the degree to which a plant is to be made flexible, this could require hardware changes. Thus, both these sets of measures will require additional capital expense at power plants where ECS and/or flexibilisation is carried out. Both of these also affect the efficiency of the plant by anywhere from one to several percent. Such additional costs will lead to higher prices for electricity, to be borne by consumers.

Currently, these issues—shutdown of older plants, installation of ECS, and flexibilisation—are being treated separately. Shutdown of older plants is being recommended on the basis of age alone, usually using 25 years as the threshold. The requirement for installing ECS in power plants is governed by emission norms set by the Ministry of Environment, Forest and Climate Change (MoEFCC). The push to make coal-based plants more flexible is a more recent issue, and the exercise is now being carried out by some plants, especially ones owned by some selected utilities. All three issues are inter-related and should be treated together,[2] by balancing economic, environmental and reliability considerations. This requires that we take a long-term view that minimises system-level costs and environmental impacts. Such an approach would also require planning and an estimation of expected future output from different plants; this is likely to vary significantly by location, vintage, technology, owner type, etc.

An integrated approach would be best implemented by projecting power requirements in the medium and long run, understanding the consequential changes needed in the system mix over the long run, analysing the type of service that will be required from the coal plants and envisioning how best that may be provided. For example, while older plants are less efficient and more polluting, they have very low fixed costs. Therefore, they may be useful for service for short periods of time. Similarly, we can ask which type of ECS is best suited where, thus reducing cost of power supply but with only a marginal increase in incremental environmental impact. These savings could be spent elsewhere to offer stricter environmental controls, thus lowering aggregate emissions and, moreover, improving overall public health outcomes. A mild loosening of selected norms for a few plants is balanced by more tightening elsewhere, where the bang for buck is higher.

In the following sections of this discussion note, we identify the issues that need to be considered for each of the three categories of actions: shutting down older plants, installation of ECS, and making coal plants more flexible. At the end, we discuss an integrated and strategic approach to consider all three of these actions together.

Retiring Old Coal Plants

We looked at some of the studies recommending retirement of older coal plants to understand the rationale behind these suggestions. We provide a brief description of three of these studies.

In a paper in *Energy Policy*, Shrimali (2020) argues that plants that have a variable cost higher than the Levelized Cost of Energy (LCOE) of RE can be retired. Based on other studies, he argues that the grid can be run reliably with these retirements. He also discusses how the remaining fixed cost obligations of these 'to be retired' plants can be reduced through securitisation.

In a report, Fernandes and Sharma (2020) of Climate Risk Horizons (CRH) argue that retiring plants older than 20 years will save money for two reasons. First, it will avoid the expenditure of installing flue-gas desulphurisation (FGD) on those plants. Second, they argue, if energy now coming from these 'to be retired' plants is replaced by energy from RE sources or the power exchange, there will be savings because of the lower cost of electricity from these alternate sources. Fernandes and Sharma also recommend freezing of new coal capacity that is in the early stages of construction.

Karthik Ganesan and Danwant Narayanswamy of the Council on Energy, Environment and Water (CEEW) made a presentation on addressing coal dependence in the power sector at a webinar in July 2020 (Ganesan & Narayanswamy, 2020). They are concerned that newer coal plants, assumed to be more efficient, are often running less than older plants. They suggest using penalties or adders to the variable costs based on the age of a plant so that the situation is corrected and newer and more efficient plants run more. While their work does not discuss retirement of older plants explicitly, it uses arguments that are similar to those used by several others to support early retirement of older plants.

On the issue of a freeze on new coal capacity, we largely agree with Fernandes and Sharma. Given excess generating capacity in the country, new capacity should be built only if absolutely required. Any new capacity could easily last for the next 40 years. With the expected decline in coal's contribution to the resource mix, great caution needs to be exercised before adding any new capacity. The decision to stop or complete coal power plants already under construction will depend on their stage of completion. It should be based on a careful analysis of the costs and benefits of both options.

[2] This point was also made by Anjan Kumar Sinha, Senior Advisor, Deloitte at the webinar on "Flexibility and Improving Efficiency of Coal-Based Power Plants," organized by Power Line and GE Steam Power on October 15, 2020.

We agree that it would make economic sense to retire some old plants. But using a simple rule based on age or variable cost in comparison to RE may not be appropriate to decide which ones to shut. The long-term system level costs and environmental impacts need to be taken into account. While, for accounting purposes, the life of a coal plant is considered to be 25 years, its actual useful life is usually 40 years or longer with good maintenance. As an example, in 2017, the capacity-weighted average age of US coal plants was 39 years (EIA, 2017). Because older Indian plants are fully depreciated after 25 years, their fixed costs are very low, and they would still have 15 years of useful life left. Therefore, when considering whether to retire them after they are 25 years old, one must ensure that they will not be needed either to meet load or to provide flexible generation for the next 15 years.

The duty cycle also needs to be considered before retiring down coal plants. When a plant operates at a low PLF, say 25 percent, shutting it down doesn't affect aggregate generation much. However, that plant may be generating during the peak time only. Shutting it down would require additional capacity to replace the energy it was providing at that time of day. If this peak period is in the evening, it is also unreasonable to compare the costs, variable or otherwise, with the LCOE of solar RE. Solar RE isn't available in the evening without storage, which is expensive.

As more RE is added, the operation of coal plants will change. A recent report by The Energy and Resources Institute (TERI) shows that as more RE is added, the PLF of some coal plants will be lower. Some plants could even be required to do two-shifting[3] (Spencer et al., 2020). Start-stop operations are quite expensive. Low fixed costs become a valuable characteristic if some plants are needed to run for very short periods, or in two shifts. The economic impact of running a new plant with very high fixed costs for very short periods would be very high. However, for older, fully-depreciated plants, it would not matter much.

Fernandes and Sharma argue that if old plants are retired, there will be savings when that energy is replaced by purchases from RE sources or the power exchange. The argument about buying energy from the exchange to substitute for energy from 'to be shut down' plants is flawed. One reason for low market prices at the power exchange is current excess capacity. If plants are shut down, or as demand grows for periods that are not RE-coincident, excess capacity will disappear and market prices will likely increase. Many studies consider daily average exchange prices, ignoring time-of-day implications. Exchange prices are likely to rise disproportionately during the evening peak period when coal plants are likely to be needed.

On the issue of instances of newer and, presumably, more efficient coal plants running less than older plants, raised by Ganesan & Narayanswamy (2020), we note that newer plants may be running less for two reasons. First, some of the newer plants may not have a power purchase agreement (PPA) and, therefore, do not get scheduled as much. Second, some newer plants may have higher variable costs than older plants and thus may be later in the merit order for despatch.

If newer plants that are more efficient are not running because they do not have PPAs, then centralised despatch using, for example, Security-Constrained Economic Despatch[4] (SCED) should resolve the issue. Rather than mandating shutdowns or penalising older plants, there should be a push for such centralised despatch. On the issue of higher variable costs for newer plants, it should be remembered that differences in variable costs do not always reflect differences in efficiency. Higher variable costs for some newer plants may be for one or both of two reasons: (1) the newer plants may be much further away from the mines and the cost for transportation may make the variable cost higher; (2) some newer plants may be using coal that is more expensive, most likely due to distortions in the framework for allocation of coal to power plants.[5] If this difference in variable costs is due to differential transport costs, it cannot be ignored because transport costs are real costs paid by the distribution company. On the other hand, if this difference is due to distortions in the pricing of coal, that should be addressed. One significant challenge is that official data sometimes do not reflect the actual coal quality delivered because of 'grade slippage', so some plants end up needing more tonnes of coal, though they are not actually operating at a lower efficiency.

For all these reasons, it becomes difficult to support blanket recommendations for retirement of coal plants based on their age. This difficulty is illustrated by data from the study carried out by Ganesan & Narayanswamy (2020, Slide No. 10). They show the daily requirement of coal at 85 percent PLF for coal plants of different age groups. Their data demonstrate that there is no direct correlation between age and coal usage (a proxy for efficiency). Plants that are 5-10 years old use less coal than plants that are 0-5 years old; plants that are in the 20-25 and 30-35-years age group use less coal than the 15-20 year and 25-30 year age group. This clearly shows that any plant's costs and operation characteristics depend on many factors and not just the age of the plant. Therefore, instead of basing decisions of retirement on vintage, it would be better to consider this on a plant-by-plant basis.

[3] Two-shifting is when a power plant is started up and shut down twice in a day to meet the requirements of the load. Coal-based power plants are designed to run continuously and are not designed for frequent switching on and off, as would happen in two-shifting. It takes several hours to bring a coal plant from shut-down up to rated output and it imposes an enormous cost.

[4] Security Constrained Economic Despatch (SCED) is an algorithm to determine the most economic generation despatch that results in the lowest overall production cost for all generators in the system to meet load while meeting all generation and transmission constraints. The Central Electricity Regulatory Commission (CERC) is considering a variant of SCED, called Market Based Economic Despatch (MBED).

[5] The price that a power plant pays for coal can vary widely, even for the same grade of coal at the same location. It depends on several factors: public or private ownership, the date of plant commissioning, whether there is a PPA or not, and whether the plant owner has an allotted coal block or has won an auctioned coal block. For a more detailed discussion on this issue, refer to Singh (2020).

All three studies discussed earlier treat the decision of early retirement of coal plants from a country-wide perspective. From this perspective, if there is overall excess capacity in the country and newer, more efficient plants are running less than older and less efficient plants, then, they ask, why not retire the older plants. It would be more rational to look at this issue in a more disaggregated manner.

Decisions about power procurement are made by distribution companies. We need to consider their perspective when discussing retirements and additions of generation capacity. Distribution companies do not own generation capacity but contract for its supply. Because they are responsible for their portfolio of supply resources, decisions about changes (retirements and additions) would be made by them. Their decisions then travel back to the owner of the capacity. In some states, this responsibility for retirements lies with the distribution company itself, such as in Punjab, where distribution and generation have not been separated. Even for most other states, where distribution and generation are unbundled, the owner of generation and distribution is the same—the respective state government—and the responsibility for retirements is then effectively with the owner of the distribution company. If there is excess capacity and old plants are mandated to be shut down so they can be replaced by newer capacity (with higher fixed costs), it needs to be clear who will be responsible for paying the additional costs. There have been some suggestions that because the debt for this new, but not fully utilised, capacity has been funded mostly by public sector banks, from a societal perspective, these should be treated as sunk costs. We do not think that would be appropriate. If a distribution company shuts down an old but fully depreciated plant and contracts for new capacity, it will add the much higher fixed costs to its payment obligations. Treating these additional costs as sunk costs to be borne by society would be an unfair shifting of responsibility for bad investment decisions.

We also note that RE is effectively 'must-run' and the states also have renewable portfolio obligations (RPOs).[6] If indeed the older plants are not required, then distribution companies themselves will retire them, as was done in Punjab with the power plant at Bathinda. Or, if the economics line up, states won't operate them if less expensive RE is available. As more RE is added, it can be sold through the power exchange. In the future, it can be bundled with storage and other sources and sold in the expectedly more sophisticated markets that come up. If such power from RE is less expensive than power from a distribution company's own portfolio, then it will buy more RE-based power. Under such a scenario, the distribution company itself will realise that some of its older and inefficient capacity should be retired. Rather than mandating shutdowns, it would be better to empower and persuade distribution companies to carry out such analyses. They can shut down plants that are uneconomic, not needed, and not expected to be needed in the future.

Emission Control Systems

In 2015, MoEFCC updated standards for power plants. These specified the maximum emissions of particulate matter (PM), SOx, NOx, and mercury as well as the norms for the discharge of water. Not only did this tighten particulate emissions, they added, for the first time, new pollutants including SOx to the list.[7] As most of the non-compliance is over SOx norms, we will focus on SOx emissions in this discussion note.

One major challenge with all analyses and planning is the lack of sufficient data on actual emissions from power plants. While plants are meant to have Continuous Emissions Monitoring Systems (CEMS), the data from these, including historical data, are not public. More importantly, CEMS are not used directly to map plant compliance but as inputs for official tests of compliance. This has two serious consequences for pollution levels: (1) periodic swings in output may be missed when checking for legal compliance; (2) plants may improve emission control performance when a compliance test is expected but may be non-compliant with norms at other times.

When it comes to SOx, the table below illustrates that, according to The Central Electricity Authority (CEA), 40 percent of the coal capacity is either in compliance or has awarded tenders for installation of FGD. Central Government plants have been the most active in this regard followed by privately-owned plants. The state-owned plants are lagging way behind, with only 12 plants, with a combined capacity of 4.32 GW, having awarded tenders for installation of FGD.

[6] Each state, and consequently each distribution company in that state, is required to have a certain percentage of its electricity from renewable sources. These obligations are known as RPOs. Each state has separate RPOs for solar and non-solar sources.

[7] Conventional wisdom was that since Indian coal has low sulphur content, no SOx control is required. This turns out to be incorrect because the sheer volume of emissions means aggregate sulphur emissions are high, more so because of the high-ash (low calorific value) coal, which necessitates greater coal throughput.

Table 1. Status of Installation of FGD.

Plant Ownership	FGD Required (MW)	Tenders Awarded (MW)	FGD Commissioned (MW)
Central	55,260	47,740	840
State	53,225	4,320	0
Private	61,237	16,600	1,320
Total	169,722	68,660	2,160

Source: CEA (2020c), Unit wise FGD implementation status and summary sheet for December 2020.

The benefits of installing FGD vary widely by location. A study evaluated this on a hypothetical power plant in eight different locations in India (Cropper et al., 2019). It carried out the following three steps, both with and without FGD: (1) estimating SOx emissions from the plant; (2) estimating the impact of SOx emissions on ambient air pollution; (3) estimating the impact of air pollution on premature mortality in the respective airshed. The reduction in premature mortality due to the installation of FGD represents its benefit. The study found the highest benefit was 28 times that of the lowest. These differences are largely due to varying sizes of the population exposed. The benefits were the highest in the densely populated states of North India, which coincidentally are also poorer.

The CEA recently carried out a study, in response to a directive from Ministry of Power (MoP), to examine the issue of plant-location specific emission standards instead of a uniform standard across the nation (CEA, 2020b). In its report, CEA stated it looked at SOx levels using satellite data and concluded that the problem of SOx emissions is concentrated in a small number of clusters in Odisha, Jharkhand, Chhattisgarh, Maharashtra, Tamil Nadu, and Gujarat. Another study carried out by IIT, Kanpur, also concluded that at distances greater than 40 km from source, the impact of the emissions was negligible. CEA recommended that plants be categorized by five levels of ground-based SOx. They suggested that ECS for SOx be required only on plants in locations which fell in the two highest concentrations. Plants in locations with SOx concentrations above 40 $\mu g/m^3$ (about 1,460 MW of capacity) should be required to install FGD immediately. Those in locations with SOx concentrations between 30 and 40 $\mu g/m^3$ (about 5,048 MW) should be required to install FGD in the next phase. It recommended that plants in locations with ground based SOx below 30 $\mu g/m^3$ should not be required to install FGD.

While we are not endorsing these specific recommendations, selective installation of FGD or specifications of technology based on location-specific environmental conditions could save a significant amount of money. However, there are two points of caution. First, assumptions and data quality can affect the results to a great extent. Second, because SOx (and NOx) emissions are contributors to secondary particulates, it is important to not limit the assessment to a narrow examination of SOx concentrations alone. The question of the magnitude of impact from secondary particulates due to SOx emissions remains unanswered–a possible gap in CEA's study. Further, selective installation of FGD would make implementation more complicated and increase the importance of good governance. A uniform emission standard is much easier to implement. If decisions on FGD installation are to be location-specific we must also ask how these decisions will be made and who will make them.

Another issue with all the approaches for reducing emissions discussed so far is that they are based entirely on upfront compliance. One advantage of this approach is its simplicity but it ignores aggregate outcomes. Many countries have operations norms that reflect day-to-day conditions, such as 'Red Alert' days. These assume importance when individual plants within an airshed comply but the aggregate pollution in that airshed is high. A related shortcoming of the simplistic approach is that it does not take into account the PLF of a plant. A plant that operates for short periods of the year has to meet the same emissions norm as another that operates at full capacity for the whole year, even though the annual emissions of the first plant may be much lower than those of the second.

This analysis is complicated further when we consider costs of compliance. There could be an FGD technology that reduces emissions to just above the norm. Such a technology cannot be used within the current approach of upfront compliance with a uniform norm. However, if the approach considered aggregate emissions, such a technology would be useful in a region with low emissions and at plants operating at low PLFs.

It is also important to remember that while FGD technologies can be very beneficial they can also create other challenges for power plants. For example, FGD leads to greater use of water. It may even cause a small drop in plant efficiency. When a plant is operated in flexible mode—more stops and starts, partial load, or variation in load—this complicates the FGD operation. It requires an augmentation of the control and instrumentation systems and changes in operating procedures (Sinha, 2020). Frequent start-ups can lead to the solidification of the slurry of limestone and water used to remove SOx. Rapid variation in load requires coordinated changes in the flow rates of the input streams for the FGD, necessitating more sophisticated automatic controls. Operating at low load levels can lead to a reduction in the inlet temperature of the flue gas, affecting the reaction rates in the FGD, and, hence, its efficacy. In addition, there can be significant decrease in the temperature of the flue gas as it exits the FGD, reducing its buoyancy and leading to corrosion in the duct and chimney.

There may be other ways to address sulphur in coal. Coal washing is an option. But we do not know if it is sufficient to meet the most stringent of norms, more so with heterogeneity in incoming coal quality.[8] Older plants, with looser emissions norms, can manage with dry limestone injection, which is cheaper than wet FGD solutions.

Given the many permutations of plant vintage, fuel characteristics, and technologies, it is not clear which approach is the most cost-effective. This is further complicated by the fact that few coal plants have coal of fixed quality, in particular, the amount of sulphur it contains. Many plants periodically or even regularly blend domestic coal with imported coal. Even CIL has delivered coal from different mines. In addition, coal from a mine may vary across different seams over the life of the mine.[9]

Making Coal Plants More Flexible

As discussed in the beginning, as more RE is added, the operation of coal plants will change. PLFs of some coal plants will be lower and some others could be required to do two-shifting. The extent of these changes will depend on how the scenario unfolds, in particular, on the volume of added RE and storage.

Three types of flexibility are required for coal plants operating under these conditions: (1) reduced minimum load level that plants need to operate at; (2) higher ramp rates both for increasing and decreasing load; and (3) a much greater number of starts and stops, particularly for two-shifting.

There are two broad categories of approaches to make coal plants more flexible. The first involves better process management through improved control and instrumentation (C&I). This approach is less expensive and easier than retrofitting a coal plant with new or modified hardware. C&I enhancements can help lower the minimum load threshold and increase the ramp rate considerably. For example, C&I changes have been used to bring down the minimum load level to 40 percent at Unit 6 of the Dadri power plant owned by NTPC. CEA reports that this required a capital expenditure of about Rs. 20 crore, which amounts to about Rs. 4 lakh per MW (CEA, 2019).[10] For comparison, the capital cost of a new coal plant is about Rs. 8 crore per MW. However, this is a relatively new plant, and older plants would require greater investment, possibly for some hardware upgrades. Equally important, the ability to achieve flexible operations as well as the investments required depend significantly on the coal quality (which not only varies by notified grade but also due to unintended variations in delivered coal compared to contracted values).

If even higher flexibility is required, for example, for very low minimum operating levels or higher ramp rates, then retrofitting would certainly be required, which is much more expensive. It also requires significant downtime for installation. Costs for retrofits depend on many factors: the type and size of the unit, its age, its operation and maintenance history, and coal quality. It is difficult to provide even an indicative estimate. In any case, such an investment, if made across all power plants, may not be required equally. Given the enormous aggregate scale of coal plants across the country, even a 'business as usual' ramping of 1 percent per minute, easily doable today, translates to an aggregate system-wide ramping of 1-1.5 GW per minute. This is sufficient to manage the expected swings of RE for the foreseeable future.

For economic reasons, plants that have higher variable costs should be asked to operate flexibly and plants with lower variable costs should be operated on a continuous basis. In general, supercritical plants are not run in extreme flexible mode because loss of supercriticality leads to reduction in efficiency. In order to ensure that sufficient flexible generation is available to meet load conditions, it is best to develop a system-wide strategy, covering all the coal plants in the generation mix of a company. This ensures that flexibility needs are met in an optimal manner.

[8] Part of governmental resistance to enhancing coal washing is because it has historically been implemented poorly, with incentives to game the system, e.g., to create higher value in the 'rejects'.

[9] CIL charges a premium to get coal from a dedicated source.

[10] Caution should be exercised when extrapolating from selected plants to all plants, especially older, smaller plants of different design (often state-owned).

Key Questions and Takeaways

- **New coal-based power capacity:** Considering expected decline in need for coal capacity, we need to be cautious in adding coal plants. New coal-based power capacity is likely to last for the next 40 years (or 25 years in accounting terms) and could end up stranded. Even for coal power plants under construction, an economic analysis should be carried out to decide whether to stop or continue construction.
- **Retirement of old plants:** Decisions about retiring coal plants, addition of FGD, and flexibilisation, should be made on a long-term, system-wide basis. It should take into consideration demand growth, costs, environmental impact, and need for flexibility in an integrated manner.[11]

  While older plants may be inefficient, they may have some advantages for distribution companies that have them in their resource portfolio:

  - Because of their low fixed cost, they can operate at lower PLFs without major economic impact
  - Subcritical plants are more suited to flexible operation than supercritical plants
  - If plants are run for short periods, installation of FGD may be avoided or solutions with lower specifications may be used. This would result in lower costs with little change in aggregate emission levels.
- **System-wide analysis by Distribution Companies:** The distribution company is responsible for long-term resource planning, power procurement, and additions/retirements of generation capacity. It should carry out the long-term system-wide analyses to decide retirements, installation of FGD, and flexibilisation. This may be challenging because of difficulties in monitoring and lack of sufficient expertise at the distribution companies. This speaks to the enormous task ahead of capacity building.

As we have shown in this discussion note, the three issues of retiring older coal plants, installing ECS and flexibilising coal plants, are interlinked. For example, older plants may be more suitable for flexibilisation. Flexible operation may be more challenging for plants with FGD. We have also seen that rather than uniform rules, a strategic approach based on location, resource mix of the utility, nature of expected load growth, and expectations about future supply and storage technologies could result in better outcomes.

Clearly, an integrated and strategic approach would require more effort than the current silo-based and simple rule-based approaches proposed in the three studies discussed earlier. The question then is whether such an approach would yield significantly better outcomes in overall costs and lowered public health impact. Would the additional effort be worth it? Also, how much delay would such changes in policy cause and would that be acceptable?

As part of this analysis, it is important to keep in mind that as effective electricity markets are established, the value of flexibility and RE, and the need for capacity adequacy will become clearer. When that happens, rules for retirement or flexibility will no longer be needed. The market will not rely only on coal plants to provide flexibility to manage the intermittency and variability of RE. It will find the best mix of flexible coal plants, natural gas-based plants, storage (including hydropower duty cycles and not just pumped hydro), and demand response for flexibility. But even before that happens, it may be best to empower and encourage distribution companies to evaluate their own resource plans and decide when to add new capacity or retire old generation capacity. That analysis and evaluation is likely to lead to faster compliance and better public health outcomes at lower cost than diktats from the government.

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[11] While studies indicate the health impacts from coal plant emissions are high enough that even "expensive" retrofits are worthwhile, counterviews suggest that some studies assume a high Value of Statistical Life. While that may be appropriate, there is uncertainty on the health benefits of incrementally reducing coal power plant emissions if these emissions are only the tail 10-20% of a high emissions burden. On an average basis, the high health impacts are there, but the same may not be true at the margin.

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