PEAKING & RESERVE CAPACITY IN INDIA

Using flexible, gas-based power plants for affordable, reliable and sustainable power

A WHITE PAPER BY WÄRTSILÄ POWER PLANTS

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EXECUTIVE SUMMARY:

India has been heavily reliant on coal for bulk of its electricity needs. Going by the recommendations of the 12th and 13th 5-year Plans, this dependence looks likely to continue well into the future. An addition of 14,000 MW of coal plants has been planned every year, on an average.

This paper cautions that focusing heavily on baseload, coal plants will lead to inefficiency and inflexibility. Power demand is increasingly following a cyclical pattern, characterised by sharp peaks during certain hours and marked troughs during off-peak hours and night. If capacity of baseload plants exceeds a certain threshold in the system, they will run at sub-optimal loads during off-peak hours. This leads to a significant drop in their efficiency. Many of the coal plants are already operating at a lower-than-normative annual plant-load factor (PLF). A major reason for this is the reduced evacuation of power during off-peak hours and night.

The problem will be exacerbated by the planned addition of renewable energy into the grid, in line with our "National Action Plan to Mitigate Climate Change". The intermittency and unpredictability of renewable energy generation will add to the problem of variability.

This paper presents a case for changing the traditional mix and pruning down the baseload coal plants to about 80% of the planned capacity, replacing the balance 20% with flexible peaking plants. The benefits of this optimized or hybrid systems are clearly visible and quantifiable.

Among the "flexible peaking" resources, hydro power is a good option where stored water is available. However it can only meet part of the national annual peak demand as its potential is seasonal and limited to a few states. Therefore a significant capacity of readily-despatchable peaking plants based on natural gas will need to be planned for.

Plants using natural gas with quick start/stop characteristics and fast ramp-up capability are ideal to meet peaking needs. They enable baseload plants to operate at optimal load and best efficiency and will come online only as needed. They will also act as a foil for the infirmness of renewable energy.

A serious reservation on use of natural gas for power generation is that it is not available in adequate quantity locally, while imported R-LNG being very expensive is an unviable choice when compared to coal.

This paper challenges that perception. Even when calculated on the basis of a high R-LNG price of US$18/MMBTU, the average energy cost in the "optimized scenario" is actually cheaper by Rs 0.14/kWh than that from the "as-planned scenario".

If planned addition of 70,000 MW over 5 years were optimized to a mix of 56,000 MW of coal plants and 14,000 MW of flexible gas plants, the overall saving would be over Rs 5,428 crores per year. If domestic gas at USD 8.4 /MMBTU is made available for peaking plants, the energy cost in the "optimized case" will be lower by Rs 0.31/kWh and the overall saving will be Rs 12,000 crores per year.

Furthermore, the flexible gas plants will offer the following benefits, over a 5-year time frame:

- The burden on investment (with the associated issues and delays in financial closure) will be lower by nearly Rs 35,000 crores.
- The requirement of land will be lower by 14,000 acres.
- The avoided water consumption will be nearly 500 million m³/year. To put this in perspective, this quantity is more than enough to satisfy the annual need of a large city like Bengaluru.
- The CO_2 emissions will be lower by 13 million tons/year. This is due to using gas for peaking and operating the baseload coal plants efficiently.
- The flexibility offered by the gas plants is of immense value in the following applications:

    a) Ancillary services: Frequency support in reducing the UI bandwidth
    b) Reserve capacity: As these plants offer the comfort of "standby reserve", they can meet a large part of the secondary and tertiary spinning reserve requirements.
    c) Load-centre servicing: Gas plants can be located close to cities/towns and reduce the strain on the transmission system. Moreover, the black-start capability of these plants will be useful in evolving an islanding scheme for important load-centres.

With the right policy framework and enabling mechanisms, it is possible to incentivise the setting up of such flexible gas plants in a very short time. This will be an important step in meeting the objective of **reliable, "24 x 7" power supply for all in the country.**

1. INTRODUCTION

India has always faced a shortage of electricity, whether measured in terms of energy generated (MU) or peak demand (MW). This problem has been – and continues to be – a serious obstacle to economic growth. While official statistics claim that the gap between supply and demand has come down in recent years, they do not factor in the unmet and latent demand from a large section of rural India.

In trying to overcome the shortage and achieve adequacy of power at lowest possible cost, the emphasis, in all our planning exercises, has been on addition of base-load thermal plants that operate on coal. At present, coal plants account for 58% of total installed capacity (MW) and about 72% of total generation (MU). Coal will continue to play a dominant role in the future too, as an average addition of 14,000 MW per year has been planned. So, in the foreseeable future, coal plants will account for about 60% of total capacity and over 65% of total generation.

This paper argues for a serious course-correction now, as it is evident that adequacy of baseload capacity alone will not help in meeting the objective of "24 x 7" power supply or in ensuring reliability. Some indicators for this are:

- Though India's total installed capacity (as on 31-3-2013) was 223,346 MW, and the peak demand was far less at 135,453 MW – there was still a shortfall in meeting the demand. Shortages continue to exist in different parts of the country.
- With the percentage of hydro-based generation in the total mix coming down in recent years, the flexibility of the system has been rapidly getting reduced.
- Coal plants are seen to be operating at close to full load during peak hours and cannot be ramped up further to overcome peak shortage. Yet, paradoxically, the average load-factor of coal-based plants has been coming down over the years, as can be seen below.
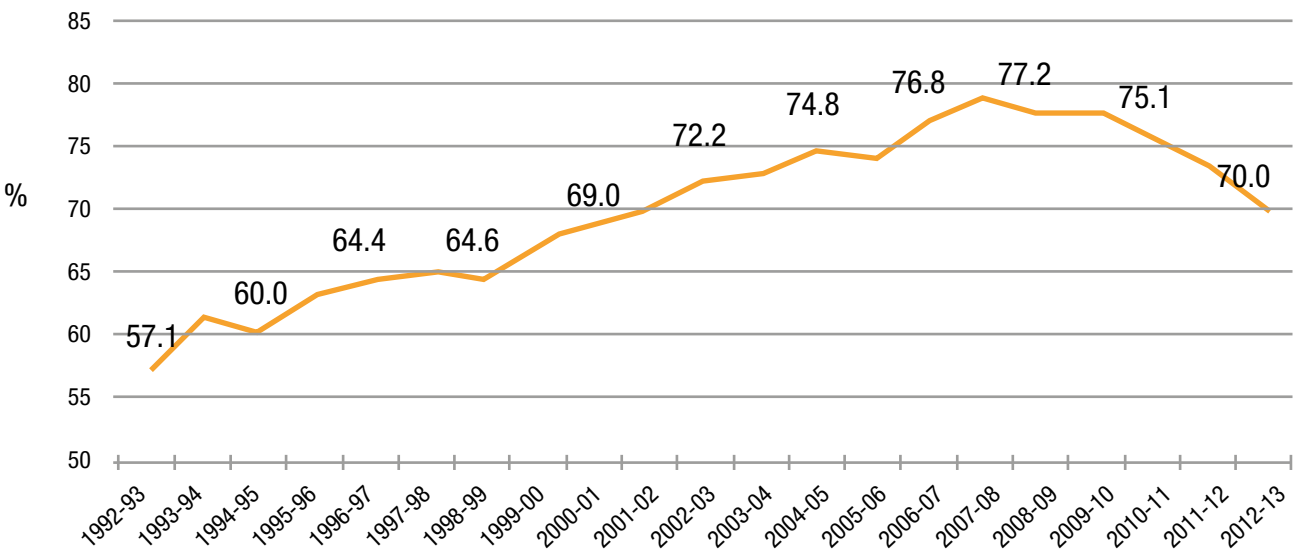
There have been several attempts to explain the trend of falling PLF. One reason cited is that inadequate coal supply severely restricted generation in many of the thermal plants and resulted in lower average despatch. But this argument does not look valid as there was no change in the trend in 2013 despite the fact that coal stock improved in all the plants.
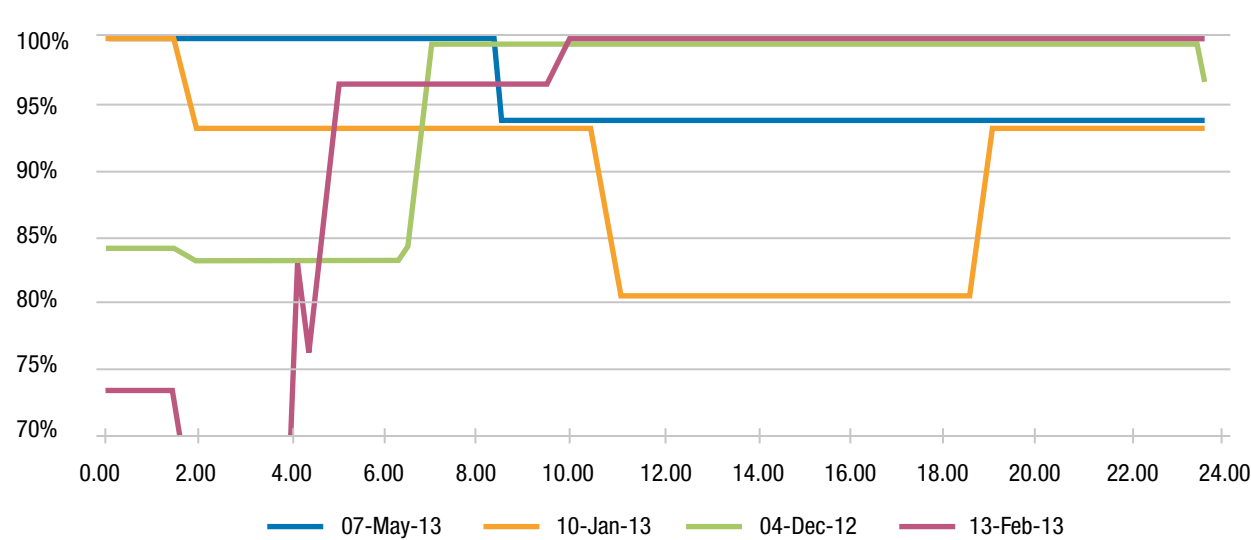
Another explanation for low PLF are the inter-state and inter-regional transmission constraints that prevent free flow of power. It is argued that once these bottlenecks are removed and when the southern grid is hooked up to the NEW grid to form a composite national grid, the offtake from coal plants would improve. Debottlenecking, strengthening and widening the transmission network in the country will, no doubt, help in balancing the load. But experience in large grids across the world has shown that the pattern of cyclical and peaking demand cannot be addressed only by improving the transmission system The Indian experience with regional grids has also shown that states try to tide over the peaking shortage by accessing the Unscheduled Interchange (UI) pool, but this can lead to high overdrawal and expose the grid to high risks of blackouts. So, more specific measures and safeguards are required.

Yet another explanation is that loss-making distribution companies (discoms) are reluctant to procure more power due to poor cost-realisation from the consumers, and would prefer to resort to load-shedding instead. This may have some basis again, but this mindset needs to be corrected with a policy that disallows the practice and insists on "24 x 7" reliability. Even when this stipulation is in place, the problem of peak demand cannot be wished away and will need to be managed with specific methods.

So, the only remaining explanation – and the most plausible one – is that the poor PLF is an outcome of a drop in power consumption during the night and off-peak hours, though the demand during peak hours continues to be high. This cyclical pattern is getting more pronounced with increased urbanisation. Generation has to be matched to meet this cyclical demand at all times.
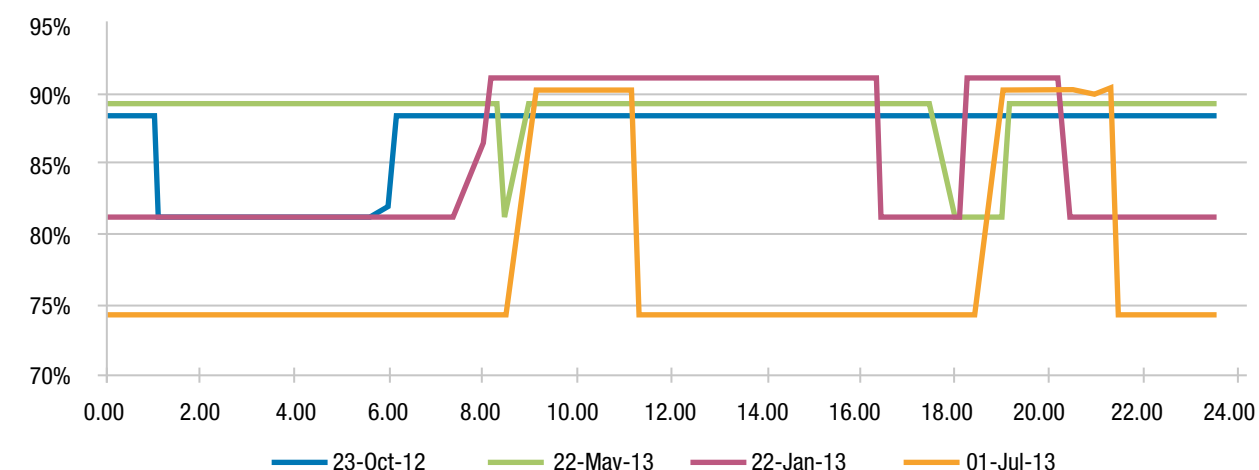
The cyclical generation pattern is evident from the daily load curve of two of the plants in Maharashtra. (Figures 2 and 3.)

Figure 1: Annual plant load factor (PLF) of coal-based power plants. Source: CEA

Figure 2: Daily load curve of Bhusawal coal power plant. Source: Mahagenco

This daily pattern, clearly visible in the two plants cited above, is discernible in many of the thermal plants across all seasons, and accounts for the poor annual PLF. The conclusion is this: If, to ensure adequacy, we keep packing the system with baseload capacity beyond a certain threshold, it can be counter-productive. The plants will be forced to operate at sub-optimal, lower load during off-peak hours and night. They will run at very poor efficiency, burning more fuel for every kWh generated and entailing more maintenance costs. This will increase the generation cost per kWh. In addition, when the plants are run at less than normative PLF, the fixed cost amortised on a kWh basis will go up in inverse proportion. Sub-optimal use of plants means also more CO_2 emissions.

Given the trend of low PLF, the problem threatens to worsen in the future. If the capacity addition of 70,000 MW of coal-based plants is done in the next 5 years as planned, the average PLF of the plants could come down to 65% or even lower while meeting the energy demand projected for the period.

Corroborating this view, NTPC (National Thermal Power Corporation), in its submission to CERC (Central Electricity Regulatory Commission) on 15-01-2014, responding to the latter's "Draft Tariff Regulations for 2014-19" has clearly pointed out the trend of declining PLF due to lower average demand.

It is also generally known that peak demand is clearly understated in India since peak demand is cut off from the system before being actually recorded.

Whenever there is load shedding, there is no estimation done of what could have been the actual peak had the supplies not been restricted. Instead, the demand at the instant of load shedding is recorded as peak demand. The actual demand is much higher but is never estimated currently. If more supplies come in to satisfy the unrestricted demand, the peaks will be even sharper, and the drop during off-peak hours more pronounced.

The problem will be rendered more acute by the planned addition of 30,000 MW of wind and solar power plants. To allow preferential evacuation from these must-run plants, the average PLF of coal plants may have to dip below 60%.

While renewable energy will be essential to meet the objectives of our action-plan to mitigate climate-change, they will pose challenges of intermittency and seasonality. Absorption of renewable energy into the grid must be achieved, overcoming these known weaknesses. A system packed with baseload plants will simply lack the flexibility or the resilience to cope with the twin challenge of variability in demand and unpredictability of renewable energy output. The system will be more vulnerable to outages. Evacuation of renewable energy will also be affected.

The report on "Transmission Plan for Envisaged Renewable Capacity" brought out by Power Grid Corporation of India in July 2012, strongly recommends that, apart from the initiatives like strengthening and enlarging the transmission network, more flexibility should be built into the generation portfolio. To quote from the report:

> "The output of the wind and solar based RE plants vary according to the available resources – the wind speed/direction and the sun's insolation level. With high penetration level of RE capacity coupled with sudden drop in generation due to unexpected cloud cover or a lack of wind can impact grid stability. Therefore fast-ramping conventional energy sources, energy storage, demand side/demand response management must be carried out to meet demand. Measures to smooth out the intermittency and variability include enlarging the balancing area, load shifting, building in more flexibility in the generation portfolio etc."

It is, therefore, clear that addition of large, baseload coal plants alone will not solve the problem of peaking shortage or aid in absorbing renewable energy. An optimal mix of baseload and flexible, peaking capacities is essential.

2. PEAKING POWER: OBSERVATIONS/RECOMMENDATIONS OF THE CEA TASK FORCE

Conscious of the need for specific action, a Task Force was constituted by CEA (Central Electrical Authority) in 2012, to deliberate over various aspects of setting up peaking power plants and creating adequate system reserves. The key observations made by the Task Force were:

- The load curves in different regions show that demand tends to peak during certain times of day and certain seasons.
- It is evident that dedicated peaking power plants are required to meet the spikes in demand. Pure baseload plants will not be able to serve this need.
- Peaking plants must have definite characteristics such as quick starting time and ability to run at part-load without drop in efficiency.
- Such plants should also serve the purpose of "standby reserve" – to come online rapidly.
- Plants that can meet the requirements are hydro-electric or gas-based power plants operated by open-cycle gas turbines or reciprocating engines.
- A certain MW of peaking plants and reserve capacity must be targeted for addition during India's 12th Five Year Plan period (2012–2017).
- Peaking power can be procured by discoms on competitive bidding basis. State regulators must allow pass-through of higher cost.

(Please see Annexure 1 for more details on the Task Force Report)

To ensure reliability of supplies and to meet the Universal Service Obligation, it is necessary, to implement the recommendations of the Task Force with a sense of urgency.

3. PEAKING PLANTS BASED ON GAS

To quote from the draft of the National Electricity Plan, Jan 2012,

"A peaking load occurs owing to several reasons. It could be something that can be anticipated, as in morning peaks and evening peaks. It could happen when irrigation needs have to be met and several thousand pump sets come on simultaneously. Urban loads can shoot up in certain seasons (example, summer airconditioning loads in Delhi). Or the peaking shortage could be due to a sudden drop in output from an infirm, renewable energy source such as wind turbines.

Peaking demand in Indian states has been met, to some extent, by purchasing power from other states through bilateral agreements or through the mechanism of Unscheduled Interchange (UI) at frequency-linked prices and sometimes by load shedding also. The frequency band tolerated here (from 50.2 to 49.5 Hz) is far above that permitted in developed countries. However in the future this frequency band is expected to narrow down and this would reduce the available margin to meet the peaking requirement or reserve capacity through frequency linked interchange mechanism. Hydro power plants also can be started up quickly to meet sudden peaks, but this facility is restricted to those few states that have adequate water storage, all through the year.

Peaking plants shall be environmentally friendly and must comply with emission norms, so as to be located close to load centres. They must be able to start up (and stop) instantaneously and ramp up quickly, and in required steps, to match the spike in load. Their efficiency curve must be high and flat at different plant loads. They must be 'all-season' plants and use a fuel which is available throughout the year."

The identified potential for hydro power is only 10,897 MW during the 12th Plan. Another 17,000 MW (apart from 17,500 MW towards reserves) of peaking capacity recommended by the Task Force must, therefore, come from gas plants that use aero-derivative turbines or large reciprocating gas engines.

Where very fast response is required – as in the case of sudden peaks and reserve capacity requirement – large reciprocating engines are being used increasingly in many countries, as they have the quickest starting and ramp-up time among all technologies that use gas.

Plants using multiple reciprocating engines can be built to any size, even 500 MW or larger, in one phase or spread over a period of time. These plants consist of multiple engines each of which operates at a high efficiency. The modularity ensures highest efficiency at any plant load, as the number of engines pressed into service can be controlled to suit the variation in load. This feature is essential as peaking demand can vary and the plant may be required to cater to different loads at different times of day. Reciprocating engines excel on this count.

The flexibility of reciprocating engines is extremely useful in countering the variability of renewable energy, as they can be brought on instantly if there is a drop in generation from such sources and stopped to allow its evacuation into the grid when its generation picks up. They thus act as enablers of renewable energy and contribute to the reduction in carbon emission.

Such flexible gas-based plants fulfil the requirement of peaking plants as described in the National Electricity Plan.

4. COST OF POWER GENERATED FROM PEAKING PLANTS THAT USE GAS

There is widespread belief that power generated from gas-based peaking plants will be far too expensive compared to that using coal and that distribution companies (discoms) will resist evacuation of such power due to the unwillingness of end consumers to pay a high price. Many examples are cited of existing gas plants in the country that are lying idle despite the willingness of gas companies to supply R-LNG, as they do not find it economically viable.

The fact is that most of the idle gas plants are based on combined-cycle gas technology and are designed for baseload operations. They cannot compete, on the merit-order, with coal plants that perform the same duty, unless domestic gas is made available to them at a special, administered price. Given the shortage of domestic gas in the foreseeable future, this is not likely. These plants could not fall back on option of using imported R-LNG as the landed cost of latter was far higher and made it unviable for baseload operations. Also, like coal plants, combined-cycle gas turbine plants lack the flexibility to start/stop quickly to be effective for cyclical duty. This is why many gas-plants in India based on combined-cycle technology have had to remain idle. Their energy cost is far higher than that of coal plant for baseload duty, and they lack the flexibility to support peaking applications.

But when gas is used for peaking duty, considerations are different. Gas-based peaking plants being enablers of reliability, the cost of power from such plants needs to be assessed in a broader perspective:

1. Peaking plants typically operate only when needed, though they are designed to operate continuously if the situation requires them to. Their annual energy output (and therefore their gas consumption and cost) will be limited to the extent of top-up demand beyond what the baseload plants cater to.

2. It is incorrect to compare the variable cost of coal-based power with that of gas-based power from peaking plants, based on thermal efficiency of former at either normative or design load. As we have seen in section 1. because of the sub-optimal PLF, the fuel cost per kWh of coal plants is much higher due to the lower average efficiency and higher average heat rate. A comparison must be done based on the actual operating efficiency of the coal plants, corresponding to the lower PLF (say 67%) of the plants.

3. Instead of viewing the cost of generation from a gas-based peaking plant on a stand-alone basis and concluding that it is too expensive, a more holistic pricing approach should be followed. A hybrid combination of coal and gas plants can be planned for, and the weighted-average cost of generation worked out. The capacity of coal plants could be limited to 80% of peak demand of the system which could then be complemented with flexible gas-based plants sized for the other 20%. The benefits:

- Coal plants would serve the baseload needs and allowed to operate at normative load (80–85%), where their efficiency is highest.
- Efficient, quick-start, gas-based plants could be used to top up the power supplies for peaking needs. Though the PLF of these plants will be less than 15% (as they will come on only during demand peaks), they will, by design, operate at their highest efficiency at all loads. Although the capacity (MW) of these plants will be fully available, the gas consumption will be limited as the energy generated annually (MU), as a percentage of total, will be low.

This hybrid combination will offer the advantages of best efficiency and flexibility. The weighted-average cost of generation from the hybrid or "optimized" combination can then be compared with that of coal plants operating at low PLF of 67%.

4. Based on a study on two representative coal plants of NTPC (at Farakka and Kahalgaon), and extrapolating the results to cover the 70,000 MW capacity addition planned during any 5-year block, the following conclusions could be drawn (the assumptions and methodology are explained in Annexure-2 of this report):

- Power from a hybrid combination of 80% coal and 20% gas is more cost-effective than that produced by the plants based on 100% coal and operating at lower PLF. This is valid even when using more expensive R-LNG instead of domestic gas.
- If the 80:20 hybrid principle is applied on the entire 70,000 MW of thermal plant capacity targeted during any 5-year block, the coal plant capacity addition can be limited to 56,000 MW, and gas-based peaking plants can make up the remaining 14,000 MW. Calculations show that the average cost of generation from this hybrid combination of plants will be cheaper by Rs 0.14/kWh than when entire addition of capacity comes from coal plants. This is after assuming a fairly high gas price of USD 18/MMBTU for operating the peaking plants. The savings spread over the entire 70,000 MW capacity would be around Rs 5,600 crores/year.
- If, in the above case, it is assumed that domestic gas priced at around USD 8.4/MMBTU will be made available for peaking plants, the cost of generation from hybrid combination will be cheaper by Rs 0.31/kWh and the cost saved over the entire 70,000 MW capacity would be over Rs 12,000 crores per year.

5. Figure 4 shows the cost of generation on coal-only basis and hybrid basis. It is seen that the average generation cost from the hybrid combination is lower than when coal plants (on cyclical duty) are used. The optimization is the result of stable and fixed generation from coal plants at higher efficiency while flexible gas-based generation takes care of the peaks.

Figure 4: Coal-gas hybrid model
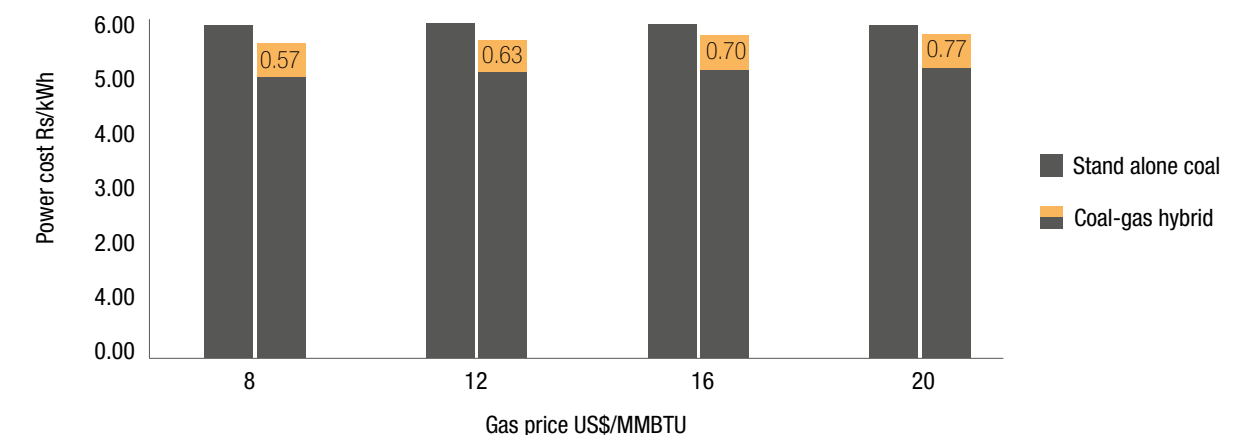
For example at RLNG cost of $16/mmbtu, the stand-alone cost of coal based plant generation at lower PLF would be Rs 5.89/kWh. Due to hybridization of Coal and Gas, the overall cost of generation could be Rs 5.71/kWh. The components of this hybridized cost are Rs 5.01/kWh from coal plants and Rs 0.70/kWh from flexible gas based plants. Thus the cost of generation of coal based plants comes down from Rs 5.89/kWh to Rs 5.01/kWh due to optimized generation at higher PLFs. (A detailed calculation is attached in Annexure 2)

6. Flexible plants complement and act as enablers of solar and wind energy. With the security of instant back-up, full evacuation from such renewable energy plants can be done without worrying about the infirmness. This means that sourcing of this power with zero variable cost can be maximized. As the "zero cost" will apply to wind and solar for all years to come, the differential will widen as the price of coal goes up.

For instance, in a state like Tamilnadu, which has a significant amount of wind capacity, the evacuation of wind energy today poses a major challenge. During high wind season, the energy from wind turbines can be evacuated only by cycling down the coal plants. Due to high variability in the wind pattern, a decision cannot be taken to shut down the coal plants as they cannot be re-started quickly if/when wind energy drops. With a limited number of hydro plants, the system that relies primarily on coal plants is found to be too inflexible to cope with the intermittency of wind as well as the daily cycles on the demand side.

By following the 80:20 hybrid principle, Tamilnadu would gain substantially. The capacity of coal plants online can be reduced by 20%, and flexible gas plants can ramp up or down instantly at best efficiency, counter-cyclic to the profile of wind energy generation.

Thus, flexible gas plants will not only enhance the reliability of the grid, but help in system-level cost optimisation by enabling baseload plants to operate at best efficiency and by allowing full evacuation of cheaper renewable energy.

Furthermore, the flexible gas plants will offer the following benefits, over a 5-year time frame:

- The burden on investment (with the associated issues and delays in financial closure) will be lower by nearly Rs 35,000 crores.
- The requirement of land will be lower by 14,000 acres.
- The avoided water consumption will be nearly 500 million m³/year. To put this in perspective, this quantity is more than enough to satisfy the annual need of a large city like Bengaluru.
- The CO_2 emission will be reduced by 13 million tons/year. This accrues on account of using a cleaner fuel like gas for peaking, as well as operating the baseload coal plants at improved efficiency.
- The flexibility offered by the gas plants is of immense value in the following applications:

  a) Ancillary services: Frequency support in reducing the UI bandwidth
  b) Reserve capacity: As these plants offer the comfort of "standby reserve", they can meet a large part of the secondary and tertiary spinning reserve requirements.
  c) Load-centre servicing: Gas plants can be located close to cities/towns and reduce the strain on the transmission system. Moreover, the black-start capability of these plants will be useful in evolving an islanding scheme for important load-centres.

5. POLICY INITIATIVES/ENABLING MECHANISMS TO PROMOTE PEAKING POWER

The fact that India is unable to meet a peak demand of around 140 GW, despite an installed capacity of over 220 GW, indicates that the system lacks the ability to respond dynamically and to ramp up quickly to meet the peak demand. This needs a technical solution in the form of dedicated peaking plants and investors must be provided the right incentives to set up such plants. As the report of the CEA Task Force on Peaking Power mentions, "adequate peaking and reserve capacity can be set up only if the prospective developer is assured of recovery of investment along with reasonable returns". If this is to happen, the following policy initiatives and enabling mechanisms must be in place.

1. Reliability standards: Clear reliability standards for 24 x 7 power supply and suitable penalties for non-conformity must be established (in line with Sec 57 of the Electricity Act) and the performance monitored by National & State Load despatch centres against these standards, so that discoms are not tempted to resort to load-shedding. As a nation, we must set and aspire for higher standards more in line with that of developed countries. Our planning process must focus on the quality of power delivered as much on the quantum of power.

The National Electricity Plan (draft, Jan 2012) states as follows:

> "The Electric Generation Expansion Analysis System (EGEAS) is a software package intended for use for expansion planning of an electric generation system. In this planning model the operation of the power system is simulated probabilistically. The load on the power system is represented both in terms of magnitude and time variation. The model yields the reliability indices, namely the Loss-Of-Load-Probability (LOLP), the expected value of Energy-Not-Served (ENS), and the reserve margin for an expansion power plan by minimising the objective function which is the present worth of the costs associated with operation of the existing and committed generating stations viz., the annualised/levelised capital cost and operating cost of new generating stations and cost of energy not served. It is proposed that an LOLP of 0.2% and the Energy Not Served (ENS) of 0.05% shall be adopted for planning purposes from 12th Plan onwards."

2. Model peaking power policy to be announced: A separate policy document that provides a clear framework for purchase and sale of peaking power and meets the objective of "24 x 7 reliability" must be published. This needs to be ratified by individual states. State regulators must permit discoms to pass on the cost of peaking power to consumers, based on time-of-day tariffs and reliability-surcharge.

3. Bids from dedicated peaking plants: Bids for peaking power must be invited from dedicated plants which have defined characteristics. If baseload plants are allowed to bid for peaking power, they will distort the "peaking market" and defeat the objective. The Model Power Purchase and Sale agreement (MPSA) seeks to allow coal plants to claim a higher heat rate corresponding to lower loads at different times of the day. This move will only increase and legitimise the inefficiency of low-PLF plants, without enhancing reliability in any way.

4. Model documents: To facilitate the bid-invitation process, model documents/templates for RFQ (request for quotation), RFP (request for   proposal) and PPA (power purchase agreement) for procurement of peaking power on long term basis, have to be published soon.

5. The tariff evaluation model must be different from that followed for evaluation of cost of generation of baseload plants, which is usually based on plant efficiency at full load. Peaking plants will operate at varying loads from 0–100%, and it is important to consider the weighted-average plant efficiency at different loads and probable number of operating hours. For instance, if peaking plants are expected to operate for 2,000 hours in a year, the model could consider the efficiencies corresponding to 100% load for 500 hours, 75% load for 500 hours, 50% load for 500 hours and 25% load for 500 hours. This will provide a more realistic estimate of the annual fuel consumption. If peaking plants are evaluated based on efficiency at a steady, fixed plant load, it will result in a distorted comparison.

6. Encourage bidding for hybrid plants: With the gradually increasing stress on the coal availability, the bidding process can offer flexibility to offer a combination of multiple fuels in the tariff bidding. This would encourage the developers to size the coal-based plants to the extent of baseload and ensure their operation at a high band of 85% PLF at the best efficiency. The fluctuating requirement can be catered by flexible power plants that are based on hydro or gas. The new MPSA must include a chapter on "Peaking Power Supply" and should encourage bids for "hybrid power" from baseload coal plants & gas-based peaking plants. That is, it should link the baseload & peak load requirement in the same bid document, providing the bidder with an option to select the right mix of both technologies that would promise the best optimization in terms of:

- Energy
- Capex i.e. capacity charge and
- The derived tariff

To illustrate the point, if the developer decides to put a 1,000 MW thermal plant, the configuration could be left to his choice. The most optimal configuration may, for example, result in 820 MW of baseload coal and 180 MW of flexible gas plant. Coal allocation for such an optimized plant can still correspond to 65% of 1,000 MW. For the balance requirement, the developer can procure the fuel – coal or gas – from other sources. This will also help the government avoid coal-based stranded assets.

While we have assumed here for simplicity that both the coal and the gas plants will be installed in the same location, the hybridization can be done at a system level even if the plants are located in two different sites. The optimal mix can be achieved on the aggregate capacity.

7. Merit-order: The merit-order mechanism must take cognizance of the pattern of variable loads and mandate a fixed percentage of power to be procured during peaking hours from dedicated peaking plants encourage dispatch from hybrid plants that are described above, by giving due weightage to the optimized cost. This way, the operator can offer power from baseload plants at best efficiency all the time, and provide top-up from gas plants during peak hours.

8. Model peaking plants: To begin with, the concept can be anchored in five of the states, by inviting bids for 200 MW plants, close to load-centres. States with high peak demand and high penetration of renewable energy must be targeted.

9. Reserve margin: This is a matter of "energy security" and must be clearly planned for and insisted upon. Without an optimal mix of primary spinning reserves and stand-by secondary and tertiary reserves, the system will be vulnerable to disruptions, affecting reliability. Every state must be asked to plan for reserve capacity.

As noted in the National Electricity Plan:

> "As regards the Reserves in the Power System, in developed electricity markets abroad, it is customary to have several layers of reserves to meet the contingencies. The first rapid response to a drop in frequency of say 0.1 to 0.2 Hz is to bring on line a hot reserve plant (equal to the largest single unit in the grid) in 5–30 seconds, through automatic generation control (AGC). As a second step, fast reserve power plants (FRPP) are started in 4–15 minutes and ramped up to full load, after which the AGC plant will retreat to reserve mode. As a third step, replacement reserve power plants (RRPP) come on in 45–60 minutes, after which the FRPP plants return to their stand-by mode. The several layers of reserves as planned in the developed countries also take care of the flexibility of operation of the various reserves. Therefore, hot reserve which is required to operate within seconds is generally provided through Automatic Generation Control (AGC). The fast replacement reserve is required to be from a generation source which is capable of ramping up within 4–15 minutes to take over from the AGC sources. However Replacement Reserve Capacity could be from slower acting generation source to take over from fast acting reserves. Accordingly, each of these reserve capacity has to be from appropriate generation source having the requisite ramp up and ramp down characteristics."

Discoms have to contract, on a long-term basis, with plants that can provide such reserve capacity – both spinning and standby- and ensure that the mandated minimum is always available.

10. Gas sale agreement: Given that flexible gas plants will require gas only during times of peaking power demand, gas companies will need to show more flexibility while contracting the minimum quantity (daily and annual) of gas to be purchased by these plants. A rigid "take-or-pay" approach will not work and will render the peaking concept unviable.

ANNEXURE 1.

Peaking Power: Recommendations of the CEA Task Force

The key observations made by the "Task Force on creating peaking capacity and reserve margin" are:
(Note: what follows is the essence and may not be a verbatim extract)

- As can be seen from various load-duration curves in different regions, the peak demand occurred during evening peak on an all-India basis in all seasons. Also the summer peak is higher than the winter peak.
- It can be seen that there are typically two periods of the day when the demand is at its peak; one in the morning and another in the evening. It can also be seen that the baseload and peak load are different in different seasons. For ensuring meeting of baseload and peak load throughout the year, we need to consider the maximum baseload and maximum peak load in the year as reference for calculating base and peak load generating capacity. This, as is seen, occurs during the summer peak in India, i.e. typically during the period May and June.
- It can be seen that there is sudden increase in demand during the evening peak in June 2012, from 107,000 MW to almost 114,000 MW, i.e. 7,000 MW in one hour, between 18.00 hrs and 19.00 hrs. The ramp rate of increase in load in other seasons is also very high, although to a lesser extent. This calls for peaking support with very high ramping rate.
- As noted by the Rakesh Nath Committee set up by CERC in 2010, **"The peak shortage underscores the need for separate dispensation to meet demands during peak periods.** The load duration curve of the country further reveals that the duration of peak demands being shorter, **it may not be economically viable to depend on purely baseload stations to meet such peak demands. It makes more sense to set up some power plants for operating only during peak period."**
- Different peak demand types need to be met by different generator solutions. In the first type of peak demand the load gradually picks up and stays like that for about 3 hours and then comes down gradually. This could be met through storage and pondage based hydro power plants (the latter during the non-monsoon period, as during the monsoon period, they would be acting as baseload power plants) and combined cycle power plants with higher efficiency. In the second peak type the load fluctuates even during the peak. These fluctuations need to be met by very quick ramp up/ramp down timing generators, of the order of seconds or a few minutes, without much loss of efficiency. **These could be met through hydro power plants, open cycle gas turbines and gas engines.**
- The operating hours for peaking power plants may be different between regions and between seasons. However, from the all-India typical daily curves, it is seen that these would operate for at least 6 hours in a day or at least 2,000 hours per year. In order to have greater utilization of assets, the peaking plants with very quick start/stop times and very high ramp up/ramp down rates of generation, could initially also act as reserve power plants during the non-peak hours.
- The quantum of peaking power plants (based on a 80:20 mix of baseload and peaking plants) and the quantum of reserve capacity (equal to 5% of installed capacity) recommended are as in Figure 5.

Figure 5: Capacity addition recommended by task force

Estimation of peaking & reserve capacity requirement	12th Plan	13th Plan
Addl. Peaking capacity	27,500 MW	28,500 MW
Addl. Reserve capacity	17,500 MW	8,200 MW
Total	45,000 MW	36,700 MW

- From system security point of view and to have reliability of supply it is necessary to have adequate system reserves in India. In view of the increasing penetration of variable generation like wind and solar power plants, higher reserves may be needed. Initially the peaking power plants could also serve to even out the variations due to wind and solar power plants during off peak hours.
- Storage and pondage type hydro power plants are capable of varying their output very quickly, as per requirement. However, hydro power plants have a long gestation period of 4–7 years. Therefore the feasibility of these plants coming up to match the required load has to be kept in view.
- Considering the 10,897 MW hydro capacity expected to come up in the 12th Plan, the remaining requirement has to be met from other type of peaking power plants, namely gas-based power plants or liquid based power plants. Since liquid based plants such as naphtha and diesel have a very high fuel charge, setting up of these plants should be avoided, until the fuel rates come down. The suitable type of plants with very quick ramp up/ramp down times is the gas-based open cycle power plants. These could be the aero-derivative type of open cycle gas turbines or IC Engines with relatively lesser capacity, in modules of say 20 MW each, so that they could start and stop quickly and each run at closer to full load, and so maintain higher efficiency, whenever they are given a signal to run. These plants would be for fine tuning of the generation requirements to match with the varying load, whether during peak hours or as reserve power plants.
- Gas-based power plants should be located near metropolitan cities, which are large load centres for three reasons: 1) to reduce transmission losses and costs 2) to help in restoration of system faster through black start in case of a blackout in the area during total or partial grid collapse and 3) to form a part of the islanding scheme of metropolitan cities, where such generation would get islanded along with equivalent load as a last resort for saving the grid, in case the same is heading for a grid collapse.
- Adequate peaking and reserve capacity can be set up only if the concerned developer is assured of recovery of his investment along with reasonable returns. Since peaking plants would operate only to cater to the peak hours, its tariff is likely to be higher. Therefore, there needs to be Time-of-Day (TOD) tariff at the retail level in the States. Recovery of fixed and variable cost of reserve power plants has to be from consumers of the States, which is to be built into the tariff.
- Gas supply: In view of shortage of gas, further gas supply for new stations should be allocated only to peaking stations. No gas supply should be allocated to baseload stations. Variable gas supply for peaking and reserve power plants should be facilitated by gas transport companies. Highest priority of gas supply to peaking power stations and reserve power plants near metropolitan cities needs to be accorded from grid security point of view to prevent complete grid collapse and for quick restoration of grid.

State Electricity Regulatory Commissions are to ensure generation adequacy for the State for meeting the energy as well as the peak requirement, as well as reserves. States must invite technology-neutral bids for peaking power, on long-term basis. States could call for bids for peaking power plant capacity and then call for bids on day-ahead basis for energy based on energy charges at that point of time. This methodology may also be followed for creation of adequate system reserves. The generation adequacy during peak and off-peak hours and the quantum of reserves would have to be specified by the SERCs, since it is primarily their function.

Figure 6: Peaking and reserve margins
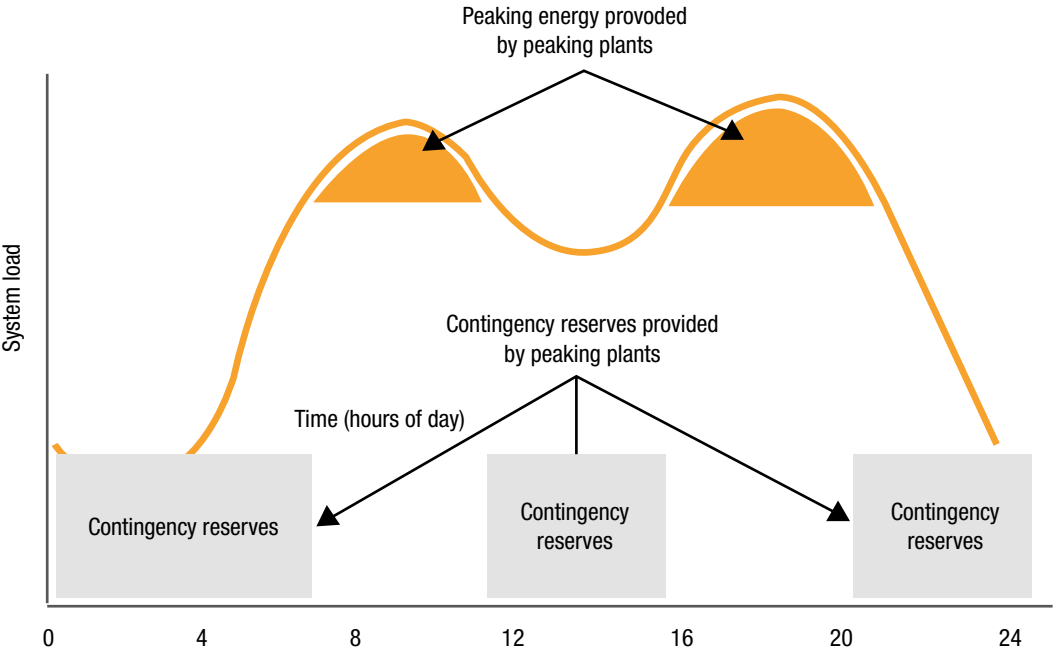
ANNEXURE 2.

Assumptions and methodology followed in calculations:

- Installed capacity: We have considered a capacity addition of 70 GW over a period of 5 years. This could be typical for any 5-year block in the future.
- It is assumed that the entire 70 GW capacity addition will be made up of critical (500 MW) and supercritical (660–800 MW) plants, considering the high efficiency of these plants during operation
- The operating PLF of plants due to new capacity addition would be around 67% which is 2% lower than the present recorded PLF of 69%. The reduction of PLF is attributable to variability in load, RE impact and reduced demand during non-peak hours.
- Capital cost of coal-based plants for critical and supercritical technology is considered at Rs 7 Cr/MW. This is based on a recent presentation made by NTPC in a public hearing at CERC on the new tariff regulations. According to NTPC, the investment cost for 14,121 MW was Rs 104,000 crores which works out to Rs 7.36 crores/MW, on an average.
- The gas-based plants are assumed to be of IC engine technology, which offers the highest operating efficiency at all loads. For IC engine the present project cost is around Rs 4 Cr/MW. Since the capacities would be added in future, we have considered a capital cost of Rs 4.5 Cr/MW in the comparison.
- Report by Task Force set up on peaking and system reserves had enumerated that ideal baseload / peak load ratio for India could be 80:20. The same ratio has been adopted for the calculation as coal capacity after optimization shall operate a baseload PLFs.
- The heat rate at 67% PLF is considered as 2,346 kcal/kWh as per MPSA DBFOO (Design, Build, Finance, Own and Operate) document. This heat rate is 2% over that at the normative PLF of supercritical plants. If, on the basis of merit order, the supercritical plants are run at normative PLF and the subcritical plants are forced to operate at lower PLF, the increase in heat rate will be far higher. We have not considered this scenario, so as to keep the exercise conservative. Due to hybridization the performance of the newly added capacity would improve heat rate to 2,300 kcal/kWh.
- An additional cost of Rs 0.10/kWh (average) has been considered in the fixed cost of the "as-planned" case to account for higher maintenance costs on boiler and turbine due to increased cycling and sharp reduction in loads during off-peak hours.
- Auxiliary power consumption of coal power plants is considered as 6% at normative PLF which is lower than 8.5% national level (2011–2012 CEA report). Auxiliary power for gas-based technology is considered 2%.
- GCV (gross calorific value) for gas is considered at 8,500 kCal/scm and gross heat rate at 1,910 kCal/kWh. GCV to NCV (net calorific value) conversion factor is 10%. 1 USD = Rs 60.

Summary of calculations:

	Unit	As-planned	Optimised hybrid					
Coal plant capacity	MW	70,000	56,000					
Gas plant capacity	MW	0	14,000					
Coal plant PLF	%	67	80					
Coal plant generation	MU	382,085	368,901					
Gas plant generation	MU	0	13,184					
Coal plant heat rate	kcal/kWh	2,346	2,300					
Gas plant heat rate	kcal/kWh		1,910					
Coal plant capital cost	Rs/crores	7	7					
Gas plant capital cost	Rs/crores	0	4.5					
Fixed cost – coal plants	Rs/kWh	3.5	2.85					
Fixed cost – gas plants	Rs/kWh		12.13					
Coal price	Rs/ton	3,100	3,100					
Gas price	USD/MMBTU		8.4	12	16	18	20	22
Gas price	Rs/SCM		19	27.1	36.2	40.7	45.2	49.8
Fuel cost – coal plant	Rs/kWh	2.39	2.34	2.34	2.34	2.34	2.34	2.34
Fuel cost – gas plant	Rs/kWh	4.31	6.16	8.21	9.23	10.26	11.29	
Weighted average fuel cost	Rs/kWh	2.39	2.41	2.47	2.54	2.58	2.61	2.65
Weighted average fixed cost	Rs/kWh	3.5	3.17	3.17	3.17	3.17	3.17	3.17
Total cost of energy	Rs/kWh	5.89	5.58	5.64	5.71	5.75	5.78	5.82
Cost saved by hybrid	**Rs/kWh**		**0.31**	**0.25**	**0.18**	**0.14**	**0.11**	**0.07**
Cost saved by hybrid	**Rs crores/year**		**11,914**	**9,475**	**6,772**	**5,428**	**4,070**	**2,712**

(More detailed calculations available on request)

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