

Improving Energy Efficiency in

Thermal Power Sector

(Achievements and Way Forward)



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Dr. Winfried Damm Head of Energy, GIZ India

Power is grown to become the fourth essential thing for living in urban areas, after air, water and food. India ranks fifth in the world with a generation capacity of 344 GW as on March, 2018. The sector has a mix of plants being of 50 years old technology to the most advanced ones. Needless to mention there exists a significant potential in renovating/ modernizing the old plants, or by simply retiring them. The Government has decided to close the old inefficient units in a phased manner giving way to the most efficient new plants. A lot of innovations in ultra-supercritical and advanced ultra-supercritical technologies are in progress which will further boost the efficiency in the sector.

Germany has been playing a very active role in promoting energy efficiency in not only its own land, but also supporting the other countries to adopt the same. Germany has been supporting India in various fields since last 60 years, with an aim of promoting cooperation and involving public-private sectors of both sides in the areas of energy, environment and sustainable economic development. The Indo-German Energy Programme (IGEN), works as a partner of Bureau of Energy Efficiency (BEE) in supporting policies and programmes envisaged under the Energy Conservation Act, 2001.

It has been a privilege to work with BEE, the organization spearheading activities on energy efficiency in India. IGEN has been involved with BEE in the Perform Achieve and Trade since its inception, and hence it is blissful to know that the outcome of this scheme led to a huge savings in terms of CO_2 emission reduction and coal.

However, the real outcome of PAT scheme is not only the savings in terms of toe and $CO_{2^{\prime}}$ but it is the change in behavior towards energy efficiency. It is astonishing to see the amount of resources and concepts the industries have put together in achieving the target. Some state-of-the-art projects implemented in PAT cycle-I are cross cutting and could have significant potential across the sectors. Some of the positive outcomes of this scheme were the utilization of waste heat in generation of steam and power, adoption of cogeneration, use of alternate fuel and raw material, etc. This report analyses the outcome of PAT scheme in Thermal Power Plant sector in multidimensional ways and forecasts the future savings along with innovative case studies having high replication potential. The estimate suggests the cumulative energy savings from the sector till 2030 to be 45.45 million TOE, which is quite impressive.

We are delighted to be a part of this historic journey where India has been a forerunner in implementing an exceptional scheme, customized to the benefit of the industries as well as the nation. I personally feel that the deepening of this scheme in Thermal Power Plant sectors would prove a game changer in the times to come. This scheme has tremendous opportunities for regional synergies and its adaptation by other countries could lead to address the global climate issues.

Dr. Winfried Damm





ऊर्जी दक्षता ब्यूरो (भारत सरकार, विद्युत मंत्रालय) BUREAU OF ENERGY EFFICIENCY (Government of India, Ministry of Power)



FOREWORD

As we are embarking an ambitious path to provide electricity to all and raise the level of energy availability to the population across the country with limited resources at disposal; efficient use of primary energy resources is absolutely necessary.

Bureau of Energy Efficiency, under the Ministry of Power has been spearheading the promotion of energy efficiency in various aspects of the country's energy landscape, through programs such as Standards & Labelling for appliances, Energy Conservation Building Code (ECBC) for buildings and Demand Side Management (DSM) program for Agriculture and Municipality sectors.

One such flagship program for energy intensive industries namely Perform, Achieve and Trade (PAT) was launched under the National Mission for Enhanced Energy Efficiency (NMEEE). This scheme has demonstrated its value in its first cycle, in which 478 Designated Consumers have achieved 8.67 MTOE of energy savings against the target of 6.68 MTOE, exceeding by about 30 %.

With an objective to have further insight on the actions taken and other notable effects taken by these designated units in achieving the excellent results, a study has been taken up by BEE in partnership with GIZ. The report gives an in-depth analysis of the achievements, projections and success stories across various sectors covered in the first cycle of PAT scheme.

With the continued guidance of Ministry of Power, the Bureau of Energy Efficiency expresses its gratitude towards all the industries, associations and other stakeholders for their significant contribution to achieve the task of saving energy and adoption of energy efficiency measures. BEE intends to convey our congratulations to all who joined us on our collective endeavour of improving energy efficiency in the country.

(Abhay Bakre)

New Delhi: 19.09.2018

स्वहित एवं राष्ट्रहित में ऊर्जा बचाएँ Save Energy for Benefit of Self and Nation

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1. Executive Summary

In a bid to combat increasing energy consumption and related carbon emissions, the Government of India released the National Action Plan on Climate Change (NAPCC) in 2008 to promote and enable sustainable development of the country by promoting a low carbon and high resilience development path. Under the NAPCC, eight national missions were framed to focus on various aspects related to water, solar energy, sustainable habitat, agricultural, energy efficiency, ecosystems, etc. Perform Achieve and Trade scheme (PAT) is a component of the National Mission for Enhanced Energy Efficiency (NMEEE) which is one of the eight missions under the NAPCC.

PAT is a regulatory instrument to reduce specific energy consumption (SEC) in energy intensive industries, with an associated market-based mechanism to enhance cost effectiveness through certification of excess energy savings, which could be traded. Energy Savings Certificate (ESCerts) are issued to the industries which reduce their SEC beyond their target. Those companies which fail to achieve their target are required to purchase ESCerts for compliance, or are liable to be penalised. Trading of ESCerts are conducted on existing power exchanges.

PAT Cycle – I, which was operationalized in April 2012, included 478 units, known as "Designated Consumers" (DCs), from eight energy-intensive sectors viz. Aluminium, Cement, Chlor – Alkali, Fertilizer, Iron & Steel, Pulp & Paper, Thermal Power Plant and Textile were included. The annual energy consumption of these DCs in eight sectors was around 164 million TOE. The overall SEC reduction target in the eight sectors was about 4.05% with an expected energy saving of 6.68 million TOE by the end of 2014–15.

With the completion of the PAT Cycle – I in 2015, the reported overall achievement was 8.67 million TOE, exceeding the target for cycle 1 by almost 30%. The total energy saving of 8.67 million TOE is equivalent to saving of about 20 million tonnes of coal and avoided emissions of about 31 million tonnes of CO_2 . In terms of monetary value, saving in energy consumption corresponds to Rs. 95,000 million.

PAT Cycle – I has witnessed an exceptional performance from all the sectors in terms of reducing their energy consumption. The DCs have made commendable efforts to achieve energy efficiency targets by adopting various improvement measures in technology, operational and maintenance practices, and application of management techniques.

Thermal Power sector is the highest consumer of energy in PAT Cycle – I, with an annual energy consumption of 104.56 million TOE by the DCs. The summary of the achievement by the thermal power sector in PAT Cycle – I is presented in Table 1.

Parameter	Units	Values
Number of DCs in the sector	nos	144
Total energy consumption of DCs in the sector		104.56
Total energy saving target for thermal power sector in PAT Cycle – I	million TOE	3.211
Total savings achieved by thermal power sector in PAT Cycle – I		3.06
Reduction in GHG Emissions in Cycle - I	million T CO ₂	13.64
Cumulative Energy savings of PAT Impact till 2030 over BAU ¹	million TOE	45.45

Table 1: Thermal power sectoral achievement in PAT Cycle - I

144 DCs from Thermal Power Sector were given a total target of 3.21 million TOE in PAT cycle 1. The overall achievement of this sector in PAT-1 was 3.06 million TOE. According to this, the sector underachieved its overall target by around 5%. However, the achievement of 3.06 million TOE relates to only 120 DCs who carried out the Monitoring & Verification (M&V) exercise and the same submitted to BEE. These 120 DCs were given an energy reduction target of 2.58 million TOE. Under such a circumstance, the DCs have overachieved their target by 19%. The key focus of thermal power sectoral report is on the energy savings resulting from PAT scheme as compared to the business as usual scenario (BAU). The report also includes the impact of PAT on GDP of the country, sector specific data analysis, process trends, sectoral benchmarking of Net Heat Rate, success stories implemented in plants, and list of key technologies which can be implemented in the sector. Analysis has been presented until the year 2030.

^{1.} Difference of energy consumption between PAT and Business as Usual scenario(BAU)

2. Thermal Power Sector in India

Power sector, over the years, has been driven by India's increasing economic growth, attributing to the development of various infrastructural projects, and increased urbanization and industrialization. With an installed capacity of 344 GW (as on March 2018), India continues its dependency on fossil fuels with almost four-fifths of electricity generated through fossils. The percentage share by energy source of power generation is shown in Figure 1.

HIGHLIGHTS OF POWER SECTOR IN INDIA

- India is ranked 5th in overall power generation capacity and 3rd in overall generation
- India's installed capacity stands at 344 GW as on March, 2018
- Electricity demand forecasts estimates as increase of 7% CAGR
- Govt. of India develops roadmap to achieve 175 GW capacity in Renewable Energy by 2022
- India's share of installed renewable capacity stands at 20% as on March 2018



Figure 1: Share of energy by source

^{3.} Central Pulp & Paper Research Institute (CPPRI) Annual Report 2014-15



Figure 2: Energy Generation and growth from conventional sources

The installed capacity of thermal power plants in India has increased at a significant pace with a CAGR of 6.44% over 3 decades. The graphical illustration of the energy generation and the percentage annual growth is shown in Figure 2. It can be inferred from the graph that the dependency on power through fossils is projected to remain mercurial, due to various reasons such as gaining publicity and installation of renewable energy projects, enhanced energy efficiency, government policies and regulations, etc.

Capacity Addition during 2017-22 and 2022-27						
YearCoal (MW)Hydro (MW)Nuclear (MW)Gas (MW)Committed RES Capacity (MW)Retirement (MW)						Retirement (MW)
2017-2022	47,855	6,823	3,300	406	175,000	22,716
2022-2027	46,420	12,000	6,800	0	275,000	25,572

Table 2: Capacity Addition of various energy sources from 2017-2027, NEP - 2018

The total coal requirement in the year 2021-22 and 2026-27 has been estimated as 735 MT and 877 MT respectively including imported coal of 50 MT. However, to cut down the coal consumption, India is pushing hard to promote supercritical units and energy efficiency on one hand while retiring the old inefficient units on the other. India witnessed a boost to supercritical technology-based coal power plants contributing to around 42% of the total capacity addition from coal-based plants during 12th five-year plan (2012-2017). It is estimated that around 20.69 Million Tonnes of CO₂ emissions has been avoided by 31st March, 2017 due to commissioning of super-critical technologybased coal power plants vis-à-vis the scenario if only subcritical units had been commissioned. R&M/LE has also been considered to improve the efficiency of the existing older units, of which 37 units with aggregate capacity of 7,202.6 MW have been completed during till 31st March, 2017.

On the other hand, gas based plants are considered

necessary to reduce CO₂ emissions and to utilize their capability to fast ramp-up and ramp-down thereby easing the process of integration of renewable energy. Modern combined cycle gas turbines (CCGTs) have high efficiency of around 55% as compared to coal-based plants. However, the production and supply of gas had not been keeping pace with the growing demand and hence the supply for gas-based power stations in the country has been inadequate resulting in huge generation loss. Against a total domestic natural gas allocated to power projects of 87.05 MMSCMD, the total gas supplied to these gasbased power plants during the year 2016-17 was only 29.59 MMSCMD. It has been estimated that the gas-based stations shall need at least 45.27 MMSCMD of gas to meet the balancing and peaking requirement of the grid arising due to

RES integration. If the storage devices become economically viable in future, then they can also be used for the balancing. Presently, existing gasbased power plants are operating at very low PLF of about 23% and few gas-based power plants are lying idle due to non-availability of domestic natural gas.

India has set an ambitious target of 175 GW of installed capacity from renewables by 2022, of which 57,244.24 MW has already been installed till March-2017. The Renewable Energy Generation will contribute about 20.1 % and 24.4 % of the total energy in 2021- 22 and 2026-27 respectively. It is estimated that about 268 Million Tonnes of CO_2 emission will be avoided annually by the end of the year 2021-22 due to the addition of renewable energy sources.

2.1 Sectoral Contribution to Country's Economic Value

Power sector is considered as a key industrial sector and an important contributor to the nation's economic growth. With rapid rise in the electricity demands, the power sector has increased the generation capacity over the years, for which the year-on-year percentage growth of gross generation from all sources and thermal sources is tabulated in Table 3.

Vara	Gross gene	ration (BU)	% Growth		
Tear	All India	From Thermal	All India	Thermal	
2012	912	859	_	_	
2013	967	904	5.9	5.2	
2014	1049	978	8.5	8.2	
2015	1107	1062	5.6	8.6	
2020	1438	1129	5.4	1.2	
2025	1839	1244	5.0	2.0	
2030	2404	1438	5.5	3.0	

Table 3: Percentage growth of units generated year on year basis³

As on 2012, almost 94% of India's electricity demand is catered by thermal power plants. With gaining popularity of renewable energy, it

is projected that the thermal power sector will constitute only 60% of India's total electricity demand.

³ All projections are based on NEP, 2018

Financial Year	Total Energy Consumption of India	Gross Domestic Product (GDP)	Energy Intensity
	million TOE	Billion USD	MTOE/ million USD
2008	427	1,187	360
2009	453	1,324	342
2010	512	1,657	309
Average Baseline	464	1,389	334
2015	659	2,102	313
2020	1018 ⁶	3,018	337
2025	12117	4,233	286
2030	14407	5,937 ⁹	243

Table 4: India's energy intensity

The Energy Intensity of the country is given in Table 4. Energy Consumption of DC's of thermal power sector covered in PAT cycle – I is 104.56 million TOE. The contribution of DC's to overall energy intensity of India's GDP is 22.5% for baseline year. The thermal power sector has achieved 3.06 million TOE savings under PAT cycle – I. The contribution of this energy savings to overall energy intensity of India's GDP is 0.46% for assessment year.

The energy intensity for the thermal power sector is given below in Table 5. It can be inferred that the energy intensity of the sector is projected to be 59.79 MTOE/Million USD by the year 2030.

⁴ BP Statistical Review of World Energy 2016

⁵ GDP from World Bank GDP for India - Upto 2015

⁶ India Energy Outlook, Year 2015 - IEA

⁷ Estimated by calculating CAGR for 2020 and 2040 in India Energy Outlook, Year 2015 - IEA

⁹ GDP values calculated based on GDP growth rateof 7.5% till 2020 and 7% between 2020 and 2030. Same assumptions have been considered in India Energy Outlook, Year 2015 - IEA

Financial Year	Total generation	Total Energy Input	Gross Domestic Product (GDP)	Energy Intensity
	Billion units	million TOE	Billion USD	MTOE/ million USD
Average Baseline	564	156 ¹⁰	1,389	112.31
2015	978	262	2,102	124.64
2020	1129	289	3,018	95.75
2025	1244	311	4,233	73.47
2030	1438	355	5,937	59.79

Table 5: Thermal power sectoral energy intensity

Thermal power sector energy intensity contribution in baseline year and assessment year was 33.6% and 39.82% respectively

The energy consumption of the sector for PAT Cycle-I was 104.56 million TOE, whereas the total energy input to sector was calculated as 156

million TOE. The energy consumption has been calculated by offsetting the energy carried by the electricity exported to the grid.

^{10.} The energy input to the thermal power sector under PAT Cycle - I is considered

3. Process description of Thermal Power Sector

Coal Handling

The coal is stored in a storage yard and is then sent to the primary and secondary crushers for reducing the size of the coal to coarse size. It is stored and then fed to boiler through conveyer. Coal from nearby coalfields is transported to the plant site and crushed to the required size. This crushed coal is conveyed to boiler bunkers and from the bunkers; the coal is fed into the boiler furnace.

Boiler

The boiler system is used to convert water to superheated steam under high pressure and temperature conditions. The heat necessary for boiling the feedwater is supplied by the heat obtained from combusted coal inside the boiler. Other fuels such as natural gas, diesel, lignite, etc. are also used as combustion materials. Larger sized power plants includes reheat of steam, which is extracting the outlet steam of HP turbine and reheating the steam to increase the enthalpy of the steam.



Figure 3: Schematic of thermal power plant

Steam and Turbine Systems

The generated superheated steam is sent to the turbine, wherein the energy is converted into mechanical energy. The turbine is coupled to a generator which generates electricity. In addition, the turbine consists of various extractions, which are passed through various HP and LP heaters, used to preheat the boiler feed water. This is a form of regenerative heat to improve the overall cycle efficiency of the plant.

Utilities

The power plant consists of a number of utilities, namely, Boiler Feed Water (BFP) pump, FD Fan, ID Fan, PA Fan, Cooling Towers, etc. In brief, the BFP is used to pump water from the deaerator to the boiler at high pressure. The PA fan is used to convey coal from the raw mill to the burner of the boiler. The FD fan is used to maintain the optimum excess air required for combustion in the boiler. The ID fan induces a negative pressure inside the boiler and discharges the flue gas to the stack. In addition, compressors are also utilized for supplying instrument air and also for conveying fly ash to the Ash Handling Plant (AHP).

Gas Turbine Systems

The gas turbine operates using NG or Naphtha as fuel to drive turbine. Almost 30% of the power generated by the turbine is utilized to run the air compressor, which is used as combustion air.



Figure 4 Schematic of Combined Cycle Gas Turbine power plant

The waste heat from the exhaust of the turbine is recovered using a Waste Heat Recovery Generator (HRSG), whose heat is used to convert water to steam and drive the steam turbine. The steam is condensed in an air cooled or water cooled condenser. The water & steam flow of the waste heat recovery boiler is similar to that of the coal based power plant, the only difference being, instead of coal, the heat is supplied by the waste heat from the gas turbine.

4. Methodology adopted for the project

The activities initiated with collection of sector specific data from Bureau of Energy Efficiency (BEE). In addition, other additional data was also collected through secondary research. The collected data were analysed to assess the impact of PAT Cycle – I on energy intensity and Business as usual vs PAT scenario, GDP of the

country, trend analysis for energy efficiency, quantification of energy saving in terms of toe and coal saving. A feedback was also collected from designated consumers on benefits and the challenges experienced through the PAT scheme.



Figure 5: Methodology followed for Impact assessment of PAT Cycle - I

The case studies were shortlisted based on higher savings, low cost implementation, innovative and with high replication potential across the sector. With the assistance of BEE, GIZ, various plant visits were scheduled and conducted across various sectors to study the technical benefits and challenges of implementing the projects. Based on the feedback from the respective plant team, success stories were developed on the same.

5. PAT Cycle-I and its impact on Thermal Power Sector

PAT scheme's primary goal is to reduce energy consumption by assigning time bound targets to the designated consumers. Any gain or shortfall in meeting the target is traded by using ESCerts, where 1 ESCert is equivalent to 1 MTOE of energy saving. This scheme is regulated by Bureau of Energy Efficiency (BEE). The existing power exchanges facilitate trading of ESCerts among DCs.

PAT Cycle – I started from 2012, with its baseline from financial years 2007 – 08 to 2009 –10. The average value of Net Heat Rate of the plant was

5.1 Impact of PAT Cycle-I

Thermal power sector has achieved 3.06 million TOE in comparison to the target of 3.21 million TOE. This achievement has estimated GHG taken for three years. The minimum threshold considered were based on the sectors. The minimum energy consumption of thermal power sector is 30,000 MTOE above which the plant is declared as a Designated Consumer (DC).

Of the 144 nos. of designated consumers, the total reported energy consumption of these designated consumers was about 104.56 million TOE. These DCs were given a target of 3.21 million TOE energy consumption reduction, which was around 48% of the total energy reduction target under PAT Cycle – I.

emission reduction of 13.64 million tonnes of CO₂ equivalent.

Energy Savings 3.06 million TOE



7.07 million tonnes of coal



13.64 million tonnes of CO₂ equivalent



Savings 33.5 billion INR



Reported Investment 32.65 billion INR

The savings are attributed to a number of measures adopted by the DCs. Where some of the DCs implemented short term measures with minimal investment, others opted for medium and long-term measures requiring considerable investment. The investment figure was reported by 48% of the DCs.

Parameter	Value
Reduction of CO ₂ emission due to implementation of PAT Cycle-1 (All sectors)	31 million Tonnes of CO_2 equivalent
Reduction of CO ₂ emission due to implementation of PAT Cycle-1 Power sector	13.64 million Tonnes of CO ₂ equivalent
Contribution to CO_2 emission reduction in overall PAT Cycle-1	44%

Table 6: Reduction in CO₂ emissions from the PAT cycle

5.2 Energy Scenario at Business as usual (BAU) vs PAT impact

The section describes the impact of PAT and comparison with BAU scenario. A summary of the performance of the sector and its projection for 2030 is mentioned in the Table 7. The impact of PAT has been assessed for PAT Cycle – I and with the current trend for energy reduction has been estimated for the year 2030.

Particulars	Unit	Value
Number of plants in the sector	Nos.	144
Baseline Energy Consumption in PAT Cycle – I	million TOE	104.56
Energy reduction target for the sector	million TOE	3.21
Energy Savings achieved in PAT Cycle - I	million TOE	3.06
Reduction in GHG Emissions in Cycle – I	million T CO ₂	13.64
Cumulative Energy savings of PAT Impact till 2030 over BAU ¹¹	million TOE	45.45

Table 7: Achievements of thermal power sector in PAT Cycle - I and projections till 2030

The energy saving of 8.67 million TOE declared for PAT Cycle – I has been calculated based on notified production for the baseline period, whereas the actual energy saving obtained will be higher while considering the subsequent production of individual sectors for subsequent years. The methodology of calculation involves SEC consumption of individual years and the achieved energy savings till 2030.

The reduction in Net Heat Rate in the baseline year from 2007 - 08, to 2009 - 10, has been calculated and considered as Business as Usual scenario (BAU). A 144 DCs from Thermal Power Sector were given a total target of 3.21 million TOE in PAT cycle 1. The overall achievement of this sector in PAT-1 was 3.06 million TOE. According to this, the sector underachieved its overall target by around 5%. However, the achievement of 3.06 million TOE relates to only 120 DCs who carried out the Monitoring & Verification (M&V) exercise and the same submitted to BEE. These 120 DCs were given an energy reduction target of 2.58 million TOE. Under such a circumstance, the DCs have overachieved their target by 19%.

^{11.} Difference of energy consumption between PAT and Business as Usual scenario(BAU)

PAT Cycle – I witnessed large investments towards implementation of energy efficient projects. These projects enabled the plants to reduce the overall energy consumption and thus Net Heat Rate of the sector. Therefore, a comparison of annual energy consumption of the sector with and without (Business As Usual) PAT would illustrate the impact of implementation of the PAT scheme and the same is projected for the future demand requirements for the sector. The projections made for the units generated have been taken from the National Electricity Plan 2018, for which the corresponding energy consumption and net heat rates have been estimated. In the projections made for the future, it has been assumed that the power generation from the diesel plants in the future will not be there and while the gas based power stations would have a PLF of 37%.



Figure 6: Energy consumption – PAT vs BAU scenario

355 million TOE energy consumption is estimated for thermal power sector in 2030 through the implementation of PAT scheme as compared to 358 million TOE energy consumption in BAU scenario

Similar comparison for the average net heat rate (kCal/kWh) for the sector is also illustrated in figure 7. In this graph, a mix of various coal, gas, and diesel based power plants have been considered to estimate the overall net heat rate

of the thermal power sector. It is observed that the net heat rate of the sector is 2679 kCal/kWh during assessment year as compared to 2768 kCal/kWh of the baseline year.



Figure 7 Business as usual (BAU) vs with PAT - Average sector net heat rate

It can be inferred that the implementation of the PAT scheme would result in total energy reduction of 45.45 million TOE till 2030.



Figure 8: A view of Thermal Power Plant

Year	GDP	Business as usual	With PAT
	Billion USD	Energy Intensity	Energy Intensity
		TOE/million USD	TOE/million USD
Baseline	1,389	112.31	112.31
2015	2,102	126.15	124.64
2020	3,018	96.48	95.75
2025	4,233	74.12	73.47
2030	5,937	60.27	59.79

Table 8: Energy intensity with PAT and BAU for thermal power sector

Assumptions considered for BAU Vs PAT calculation

Net Heat Rate

• The net heat rate of the sector has been calculated by taking into account the total generation and the total energy consumption of the sector.

Business as usual scenario:

- The plant would have undertaken activities on energy efficiency on its own, even without the intervention of PAT scheme.
- The reduction in net heat rate in the baseline year from 2007 08, 2008 09 and 2009 10, has been calculated and the same reduction is projected till the year 2030 to analyse the BAU scenario.
- The performance evaluation of the sector is also dependent on other assumptions such as
 - o Increase in share of super-critical coal based power plants
 - o Retirement of older units; particularly diesel based power plants
 - o Increased capacity of coal based and other renewable energy sources
 - o Reduced PLF of gas based power plants

With PAT scenario:

- The actual energy saving achieved in the PAT Cycle I is taken for the assessment year 2014 -15.
- The projection till 2030 is based on the savings between the Assessment year and Baseline year.
- The target will go on decreasing in the subsequent cycles owing to the diminishing potential in the plant as they go on implementing projects on energy efficiency.
- Various breakthrough technological advancement might provide further reduction potential in the sector.

5.3 Thermal power sector specific data analysis of PAT Cycle - I

The overall trend of various categories of power plants indicating the unit heat rate, APC and the

net heat rate for the assessment year is tabulated in Table 8, for PAT Cycle - I

0.1	Gross Unit	Heat Rate		APC		Net Heat Rate	
Category	National Best	Average	National Best	Average	National Best	Average	
MW	kCal/kWh	kCal/kWh	%	%	kCal/kWh	kCal/kWh	
<100	2606	3082	8.38	11.18	2908	3470	
100 - 150	2450	2718	6.92	11.48	2687	3070	
150 - 300	2274	2554	5.86	7.36	2496	2757	
300 - 600	2244	2386	5.34	6.66	2419	2556	
Gas	1837	2161	1.43	3.47	1881	2239	

Table 9: Net Heat Rate & APC (National Average Vs National Best)

In order to analyze the sectoral profile of the power industry, the units of the thermal power plants are categorized into five different segments, based according to the size of the installed capacity namely, (1) <100 MW (2)100 - 149 MW (3) 150-300 MW (4) 300 - 600 MW (5) >600 MW. Based on the data received from BEE, analysis was carried out by compiling and analyzing data for 78 TPPs and 34 Gas Turbine modules (CCGT), which is equivalent to 75% of the power plants shortlisted in PAT.

	No. of	Installed Capacity	Operat	ing Load	Gross Generation PLF			.F
Category	Units	ΑΥ	BY	AY	BY	AY	ВҮ	AY
		MW	MW	MW	MU	MU	%	%
<100	46	2,717	2,280	1,719	17,263	11,543	67.23%	62.11%
100 - 149	65	7,755	5,189	5,525	28,742	26,290	50.15%	44.46%
150 - 300	183	39,690	33,489	34,094	219,351	192,855	65.65%	56.33%
300 - 600	56	27,180	19,603	24,575	66,210	78,576	43.19%	33.00%
>600*	3	1,980	-	617	-	14,340	-	82.67%
TPP Total (A)	331	77,112	60,562	66,529	331,566	323,604	58.13%	47.91%
Gas (B)	68	10,558	7,831	6,512	63,361	32,134	68.51%	34.74%
Sector Total (A+B)	399	87,670	68,392	73,041	394,927	355,738	59.58%	46.32%

Table 10: Installed capacity and operating load for BY and AY

*The first 660 MW unit in India was commissioned in 2010, and hence, units with capacity of 660MW and beyond were not available during the baseline of PAT Cycle-I

In order to analyze the sectoral profile of the power industry, the units of the thermal power plants are categorized into five different segments, based according to the size of the installed capacity namely, (1) <100 MW (2)100 - 149 MW (3) 150-300 MW (4) 300 - 600 MW (5) >600 MW.

Based on the data received from BEE, analysis was carried out by compiling and analyzing data for 78 TPPs and 34 Gas Turbine modules (CCGT), which is equivalent to 75% of the power plants shortlisted in PAT.

% Increase				
Calanam	Op. Load	Gross Generation		
Lategory	%	%		
<100	-24.63	-33.13		
100 - 149	6.47	-8.53		
150 - 300	1.81	-12.08		
300 - 600	25.36	18.68		
>600	-	-		
TPP Total	9.85	-2.4		
Gas	-16.84	-49.28		
Sector Total	6.8	-9.92		

Table 11: Percentage increase or decrease of operating capacity and gross generation

Similar comparisons were made to analyze the trend of average unit heat rate and the net heat of the corresponding categories. Based on the analysis, the trend of the same was also evaluated. The unit heat rate of all the categories, with the exception of 300 – 600 MW units, have decreased by at least 2% (on weighted average) for the thermal power plants. The unit heat rate

of 300 – 600 MW segment and the gas turbine modules increased by at least 2%. Majority of the units operate with gross unit heat rates deviating by up to 10% with respect to the design heat rate, wherein the plant load factor and decreasing gross generation have been detrimental to the gross unit heat rate.

	Gross Unit Heat Rate (Wt. Avg)						
Category	Design	BY	AY	Range BY	Range AY		
	kCal/kWh	kCal/kWh	kCal/kWh	kCal/kWh	kCal/kWh		
<100	3,476	3,205	3,082	2,606 - 3,886	2,606 - 3,940		
100 - 149	2,802	2,967	2,718	2,321 - 3,886	2,213 - 2,678		
150 - 300	2,306	2,603	2,554	2,275 - 3,182	2,273 - 3,138		
300 - 600	2,263	2,326	2,386	2,226 - 2,976	2,244 - 2,835		
>600	2,207	-	2,284	-	2,272 - 2,293		
Gas	1,956	2,114	2,161	1,807 - 4,503	1,837 - 4,780		

Table 12: Unit Heat Rate comparison of assessment and baseline year

The following table is the evaluation of the percentage increase or decrease of unit heat rate and the deviations of the heat rate in the

assessment year and baseline year, with respect to design.

	0/ 1======	Deviation w.r.t. Design	
Category	% Increase	ВҮ	AY
	%	%	%
<100	-3.85	-7.78	-11.34
100 - 149	-8.41	5.9	-3.0
150 - 300 –1.90		10.31	8.21
300 - 600 2.55		2.8	5.42
>600	-	-	-
Gas	2.25	8.1	10.53

Table 13: Percentage increase or decrease of unit heat rate

Similar to the unit heat rate comparison, the APC of the power plant units of various categories were also evaluated and is tabulated in Table 13.

The APC% for 150-300 MW units have significantly reduce by almost 10%, while the other categories have shown an increase.

	Au	% Increase			
Category	ВҮ	AY	Range BY	Range AY	APC
	%	%	%	%	%
<100	10.40	11.18	7.98 - 14.26	8.38 - 15.39	7.5
100 - 149	11.06	11.32	7.38 - 19.76	6.92 - 21.78	3.8
150 - 300	8.85	7.36	4.53 - 14.26	5.86 - 14.54	-16.84
300 - 600	6.37	6.66	4.50 - 10.78	5.34 - 8.82	4.55
>600	-	5.34	-	5.34	-
Gas	2.59	3.47	1.68 - 10.42	1.43 - 9.67	33.98

Table 14: APC comparison of assessment and baseline year

The decreasing net heat rates of the thermal power sector from 2768 kCal/kWh in the baseline period to 2712 kCal/kWh in the assessment year is the result of the implementation of the PAT scheme, wherein the wt. average net heat rates of various categories can be observed in Table 14. As indicated below, the reduction of net heat rates of various categories is a testimony to the 2% reduction achieved by the sector during PAT Cycle – I.

		% Increase			
Category	BY	AY	Range BY	Range AY	Avg Net HR
	kCal/kWh	kCal/kWh	kCal/kWh	kCal/kWh	%
<100	3,577	3,470	2,870 - 4,532	2,908 - 4,300	-3.01
100 - 149	3,336	3,070	2,506 - 4,559	2,687 - 4,861	-7.97
150 - 300	2,856	2,757	2,492 - 3,661	2,496 - 3,506	-3.48
300 - 600	2,484	2,556	2,413 - 3,277	2,419 - 3,014	2.87
>600		2,413	-	2,400 - 2,422	-
Gas	2,170	2,239	1,843 - 4,613	1,881 - 5,072	3.17

Table 15: Net heat rate comparison of assessment and baseline year

Supplementing the analysis illustrated above, comparisons were made to analyze the number of cold/warm/hot boiler startup during baseline and assessment year. It can be inferred from Figure 9 that, for the overall thermal power sector, the number of cold/warm startup have increased by almost one-third and the number of hot startups have reduced by 23%. It is imperative to understand that, particularly the 150–300 MW category has experienced a majority of these cold/warm startups, increasing almost two-fold in the assessment year.



Figure 9: Comparison of no. of startups for BY and AY in PAT Cycle - I

The variation in the number of cold/warm/hot startups can be attributed to various factors:

- Decreasing PLF of the power sector/Load scheduling
- Resource unavailability (fuel, water, etc.)
- Environmental compliances
- · Surplus electricity resulting in lower peak

demands, hence, decreased hot startups in AY

All of the aforementioned factors are not only an indication of the sector's operational efficiency, but also reflects on the primary energy consumed by the sector. The percentage share of the primary energy consumption of the sector for the baseline and the assessment year are shown in Figure 10.



Figure 10: Share of primary energy consumption in BY and AY in PAT Cycle - I

The percentage share of the primary energy consumption of the sector for the baseline and the assessment year is shown below. The figure evidently indicates the decrease in the consumption of liquid and gas fuels, while the consumption of imported coal has doubled between the baseline and assessment year. Based on the trends of primary fuel consumption, the following conclusions were drawn.



Figure 11: Comparison of consumption of Indian coal and imported coal

- Demand & Supply gap of coal: With India's coal reserves being able to cater to only 75% of coal requirements, and the demand for coal is increasing at a CAGR of 6% every year, the imports of coal have increased substantially in order to avoid fuel shortages.
- Fuel quality of coal: India's domestic coal is characterized as a fuel with low GCV, high ash content and high moisture content, and the alternative to blend domestic coal with imported coal provides impetus to the generating stations to operate more efficiently. The increase in imported coal consumption has increased by 4.2% as shown in Figure 11
- Increase in installed capacity: With the commissioning of larger power plants, and increase in the
 operating load of medium capacity (300-500 MW) power plants, has resulted in increased demand for
 coal
- Unavailability of gas: The utilization of NG fuel has witnessed a 4% decline between the baseline and the assessment year, majorly attributing to the low availability of gas fuel.
- Shutdown of diesel based plants: Owing to various environmental compliances and high cost of generation, various diesel based plants are also being shut down, therefore resulting in reduced consumption of liquid based fuels.

6. List of major energy saving opportunities in the sector

The implementation of the PAT scheme has mandated various industrial sectors to focus more on energy efficiency and strive to reduce the overall energy consumption. With more PAT cycles rolling out for the forthcoming years, the industries look towards various energy efficient technologies in order to achieve the respective targets.

A list of major energy saving opportunities in the sector have been identified and listed below. The projects are listed based on readiness level, co – benefits obtained by installing the system and based on expected payback range by implementing the project.

Technology Readiness Level (TRL):	Co-Benefits: PQCDSME	Payback Horizon (PB)
TRL 1 – Research (Basic or Advanced)	Productivity (P)	PB 1 – less than 1 year
TRL 2- Proof of concept	Quality (Q)	PB 3 – 1 year to 3 years
TRL 3- Demonstration(Pilot)	Cost(C)	PB 5 – 3 to under 5 years
TRL 4- First of a Kind	Delivery (D)	PB 8 – 5 to under 8 years
TRL 5- Fully Commercial	Safety (S)	PB 12 – 8 to under 12 years
	Moral (M)	PB >12 - over 12 years
	Ethics, Environment (E)	

S No	Energy Saving Opportunities	Co-Benefits	Technology Readiness Level	Payback Band
1.	Installation of VFD for CEP, ID, FD and CT fans	P, C, E	TRL – 5	PB 5
2.	Micro Oil Ignition System (MOIS)	P, C, E	TRL – 4	PB 5
3.	Installation of Dynamic Classifiers for Coal Mills	P, C, E	TRL - 5	PB 5
4.	Installation of VAM using waste heat from flue gas	С, Е	TRL – 5	PB 5
5.	Installation of energy efficient pumps	С, Е	TRL - 5	PB 5
6.	Energy efficiency in electrical equipment (EE motors)	С, Е	TRL - 5	PB 5
7.	Cooling tower upgradation (Retrofitting of CT)	С, Е	TRL – 5	PB 3
8.	Installation of centrifugal compressors in place of reciprocating/screw compressors	C, E	TRL - 5	PB 3
9.	Installation of LP compressor for fly ash unloading	С, Е	TRL – 5	PB 3
10.	Installation of Advanced Rotary Air Preheater (high heat gain)	С, Е	TRL – 4	PB 3
11.	Installation of screw vacuum pump in place of vacuum ring pump	C, E	TRL – 4	PB 3
12.	Installation of online optimization software (Combustion, Boiler, Turbine)	C, S, E	TRL – 4	PB 3

7. Success Stories – Case Studies in Thermal Power sector

7.1 Modifications of CT Make Up through Gravity

Introduction

The project was implemented at 0 P Jindal Group, Tamnar, Chhattisgarh. Pumps contribute to a significant amount of energy usage in the power plant, finding applications in the form of Boiler Feed Water Pumps (BFP), Condensate Extraction Pumps (CEP), Cooling Water Pumps, Make-Up pumps, etc. While designing a pump, it is essential to look into various factors and one such factor is the utilization of available head, wherein the gravitational force of the fluid is utilized. In this instance, the plant operates a pump for CT Make Up from a CT sump, thereby consuming significant amount of energy. Utilization of gravity resulted in the lesser operating hours of the CT pump by connecting the tank outlet for the process requirement.

OP Jindal Super Thermal Power Plant, a subsidiary of Jindal Steel & Power Limited, commissioned the 4 x 250 MW becoming the first private player to set up 1000 MW in the Independent Power Plant segment.

Description of the project

The plant has installed 3 nos. of CT Make Up pumps in each phase of the 4 x 250 MW thermal power plant, wherein each phase consists of 2 x 250 MW installed capacity. Two pumps are in operating condition while one pumps is in standby mode. The technical specifications of the CT Make Up pumps are tabulated below:

Description	CT-make-up Pumps
Pumps capacity	6 X (910 m³ /Hrs.)
Head	20m WC
MOC/TYPE	CI/Vertical Turbine
Make(Drives)	WPIL
Model	E 18TC-1 stage
kW/RPM	90/1500
Make(Motor)	Crompton Greaves
Liquid handled	Clarified water

Before modifications

Two pumps are operated in each phase at an average rate of 13 - 14 hrs/day to meet the

demands for the CT make up requirements. The pumps are located on the top of clarified water storage tank and it discharges water from the storage tank to Cooling Tower sump located around 0.5 km for Phase–I and approx. and 1.2 km for Phase–II through underground discharge pipeline. The power consumption of the 90 kW rated pump was consuming around 119A - 123A consuming approximately 70 kW per hour.



Figure 12: Illustration of modified project

The height of the clarified water storage tank is 5m with a storage capacity of approximately 16000m³. The height of the water stored in storage tank provides a natural head of approx. 0.4 kg/cm^2 for the water to be discharged through gravity. Initially modification was done only for Phase-I where a spool pipe (600 NB - same as the discharge line) was erected from the bottom of the storage tank and it was connected to the CT Makeup Discharge Outlet line and an isolation valve was provided in between the tank and the outlet line. In case of make-up requirement the valve is opened and water is discharged through natural head of the storage tank. In case the level of the CT sump is critically low then the valve is isolated and water is discharged with



Figure 13: CT makeup Pump House

the help of pump as per original scheme. The pump operating time is recorded and logged for calculating the power consumption. It has been observed that the pump is usually not required to be operated for normal operations. After successful implementation of modification similar modifications were carried out for phase-II.

Benefits:

The following benefits have been achieved by the plant:

- Auxiliary power saving 0.582 million units per annum.
- Reduction in CO₂ emissions



Figure 14: New Gravity Makeup Line

Parameters	Value
Energy savings	0.582 MU
MTOE equivalent savings	147.12 MTOE
Cost Savings	Rs. 1.5 Million
Investment	Rs. 0.06 Million
Payback(months)	1
GHG reduction	515 tCO ₂ equivalent of GHG reduced
	15% of plants in the sector can opt for this technology
Replication Potential	Reduction of 2,920 MTOE anticipated for the sector

Contact details for the project		
Plant Name	0 P Jindal Group - Tamnar	
Person to be contacted	Pratik Bose	
Designation	Head - Technical Services	
Contact number	9329444839	
Email - ID	pratikkumar@jindalpower.com	
Address for communication	0 P Jindal Group - Tamnar	

7.2 Low Grade Flue Gas based Vapour Absorption Machine (VAM)

Introduction

The project was installed at NTPC, Ramagundam, Telangana. Most of the industrial process uses a lot of thermal energy by burning fossil fuel to produce steam or heat for the purpose. After the processes, heat is rejected to the surrounding as waste. This waste heat can be converted to useful refrigeration by using a heat operated refrigeration system, such as an absorption refrigeration cycle. Both vapour compression and absorption refrigeration cycles accomplish the removal of heat through the evaporation of a refrigerant at a low pressure and the rejection of heat through the condensation of the refrigerant at a higher pressure. The basic difference is that an electric chiller employs a mechanical compressor to create the pressure differences necessary to circulate the refrigerant whereas the absorption chillers use waste heat source and do not use a mechanical compressor.

National Thermal Power Corporation is a major power generation corporation in the country. NTPC Ramagundam, a part of National Thermal Power Corporation has installed capacity of 2600 MW; Stage 1: 3 units each of 200 MW, Stage 2: 3 units each of 500 MW, Stage 3: 1 unit of 500 MW.

Description of the project



Figure 15: Utilization of low grade flue gas in VAM

The schematic diagram of flue gas based VAM is shown in the figure above.

The objective of NTPC Ramagundam was to utilize waste heat from flue gas for air conditioning as a proof of concept, pilot plant (100TR) at Unit-4 Ramagundam STPS. The project was supported and funded by NETRA (NTPC Energy Technology Research Alliance). This Project was a Pilot Project conceptualized by NTPC NETRA (R&D division), the first of its kind in India wherein the 100TR Air-Conditioning was generated out of Exhaust from a thermal power Plant for cooling of their various ESP rooms. The flue gas based VAM was installed at Stage 2, Unit 4 (500 MW) on 25th October 2013. It was implemented during unit overhauling and hence shutdown was not required and the plant has two other VAMs installed at their site, Stage 1 Unit 1 and Stage 3 Unit 7, which uses auxiliary steam (PRDS system). The waste heat recovery system is designed to recover 500 kW of thermal heat from flue gases to produce 100 tons of refrigeration.

The VAM is a "BROAD" make absorption chillers supplied by ICL in which waste heat from flue gas is used as heat source to run the system. The chilled water is generated from VAM, which is distributed to different locations (ESP Unit 3, 4, 5 Control Rooms) for Air conditioning.

Working Principle:

The input heat energy heats LiBr solution to generate vapor, which is then condensed into water by cooling water. When the refrigerant water enters the evaporator (in high vacuum condition), its temperature goes down immediately and it is sprayed over the copper tubes to produce cooling.



Figure 16: Basic working principle of VAM

The water absorbs heat from the air conditioning system and evaporates, then it is absorbed by concentrated LiBr solution from the generators. The cooling water takes away the heat and releases it into the air. The diluted solution is pumped into the high temperature generator (HTG) and the low temperature generator (LTG) separately to be heated to begin the process all over again.

The figure shows absorption refrigeration systems replace the compressor (as compared to vapour compression refrigeration) with a generator and an absorber. Refrigerant enters the evaporator in the form of a cool, low-pressure mixture of liquid and vapor (4). Heat is transferred from the relatively warm water to the refrigerant, causing the liquid refrigerant to boil. Using an analogy of the vapor compression cycle, the absorber acts like the suction side of the compressor—it



Vapour Absorption Machine (VAM)

draws in the refrigerant vapor (1) to mix with the absorbent. The pump acts like the compression process itself and it pushes the mixture of refrigerant and absorbent up to the high-pressure side of the system. The generator acts like the discharge of the compressor and it delivers the refrigerant vapor (2) to the rest of the system.

The refrigerant vapor (2) leaving the generator enters the condenser, where heat is transferred to water at a lower temperature, causing the refrigerant vapor to condense into a liquid. This liquid refrigerant (3) then flows to the expansion device, which creates a pressure drop that reduces the pressure of the refrigerant to that of the evaporator. The resulting mixture of liquid and vapor refrigerant (4) travels to the evaporator to repeat the cycle.



Flue gas based VAM system

Benefits:

The following benefits have been achieved by the plant:

- Air conditioning using waste heat instead of electricity or auxiliary steam.
- Free from ozone depletion substances (R12/ R22)
- Step toward 100% phase out of HCFC, as the VAM system is free from greenhouse gases
- Scale-up potential is good

Parameters	Value
Energy savings	0.584 MU
MTOE equivalent savings	155.55 MTOE
Cost Savings	Rs 1.34 Millions
Investment	Rs. 10 Million
Payback(months)	90 Months
GHG reduction	525 tCO ₂ equivalent of GHG reduced
	40% of plants in the sector can opt for this technology
Replication Potential	Reduction of 46,952 MTOE anticipated for the sector
	Rs. 3,130 Million Investment potential for implementing this project in the sector

Contact details for the project		
Plant Name	NTPC Ramagundam	
Person to be contacted	Mr. Kosal Ram	
Designation	AGM (EEMG)	
Contact number	9440918092	
Email - ID	kkram@ntpc.co.in	
Address for communication	NTPC Ramagundam	

8. List of Technology suppliers

S No	Company Name	Technology	Website link		
1	Armstrong International Pvt. Ltd.	Steam and Condensate solutions; Utility systems & optimizations	www.armstronginternational.com		
2	Cethar Ltd.	Water/Waste water systems, Fuel/ Material handling	www.cethar.com		
3	Forbes Marshall	Steam traps, Steam monitoring systems, condensate pumps, heat exchange solutions	www.forbesmarshall.com		
4	ISGEC Heavy Engineering Ltd.	Manufacturing & Supply of Power Plants; Boilers (Pulverized Coal fired Boilers, Oil & Gas fired Boilers, CFBC Boilers, AFBC Boilers, etc)	www.isgec.com		
5	L&T – MHPS Boilers Pvt Ltd	Pressure parts & pulverizers for supercritical boilers	www.lntmhps.com		
6	Paharpur Cooling Towers Ltd	Wet cooling towers, air cooled steam condensers, air cooled heat exchangers	www.paharpur.com		
7	Lloyd Insulations	Rockwool Insulation, Ceramic Fibre, standing seam Roofing sheeting, Refractory work, Mechanical and Piping, electric Heat tracing, Fire- fighting system	lloydinsulations.com		
8	Sound Blast Sonic Power Co. Ltd.	Energy Efficient Technology sonic soot blowing	sound-blast.com		
9	Thermax Ltd.	Heating Equipment, Absorption Chillers, Power & Captive Cogeneration Plants, Waste Heat Recovery Units, Air Pollution Control Equipment, Water & Waste Solutions	www.thermaxglobal.com		

Table 17: List of key technology suppliers in Thermal Power Sector

Abbreviations

В

ΒA	U						
	Business as usual	2,	6,	16,	17,	18,	19
С							
CA	GR						
	Compounded annual growth	n r	ate	1			9
CO,	2						
	Carbon dioxide				9,	10,	16
Ε							
ES	Certs						
	Energy saving certificates						5
G							
GD	P						
	Gross domestic product				6	i, 7,	16
I							
IEA	4						
	International Energy Agenc	y				9,	10

Μ

mMTOE	
million metric tonne of oil equivalent	16
million metric tonne oil equivalent	5

Ρ

PAT Perform, Achieve and Trade 2, 3, 4, 5, 6, 10, 14, 15, 16, 17, 18, 19, 21, 1, 2, 3, 5

S	
SEC	
Specific energy consumption	5, 16
Т	
TOE	
Tonne of oil equivalent	14, 15

U

USD		
United states dollars	9,	10



Bureau of Energy Efficiency

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