सत्यमेव जयते
Ministry of Power
Government of India

Improving Energy Efficiency in

Fertilizer Sector

(Achievements and Way Forward)

Perform Achieve & Trade

September 2018

ऊर्जा जीवन है, संरक्षण करें
बी ई ई
BEE
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BUREAU OF ENERGY EFFICIENCY

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India contributes to 16.82% of global fertilizer production and ranks second in its consumption. The production process involves large amount of energy making it one of the high energy intensive sectors. The Indian fertilizer sector is a highly regulated sector, where subsidies are given to the industry by the Government. The sector is estimated to grow around 3% annually. The fertilizer industry in India is world class in terms of technology and efficiency levels. However, to further reduce the energy consumption, there is a significant scope of R&D and technology transfer 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, 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 Fertilizer 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 12.95 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 Fertilizer 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

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सत्यमेव जयते

ENERGY IS LIFE
CONSERVE IT
ऊर्जा 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.
(Abhay Bakre)

New Delhi: 19.09.2018

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1.0 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-I 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.

Fertilizer sector is the fourth largest consumer of energy in PAT cycle-I, with an energy consumption of 8.20 m MTOE. A brief achievement by the fertilizer sector at a glance is mentioned in the Table 1. The key focus of fertilizer sectoral report is on the energy savings and GHG reductions 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 specific energy consumption, 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.

Parameter	Units	Values
Number of DCs in the sector	nos	29
Total energy consumption of DCs in the sector	million TOE	8.2
Total energy savings target for fertilizer sector in PAT cycle–I		0.478
Total energy savings achieved by fertilizer sector in PAT cycle-I		0.780
Energy savings achieved in excess of the target		0.302
Reduction in GHG Emissions in cycle-I for the Sector	million T CO_2	0.93
Cumulative energy savings of PAT Impact till 2030[1] (over BAU)	million TOE	12.95

Table 1: Fertilizer sector- achievements in PAT Cycle – I

The focus of chlor alkali 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 specific energy consumption, 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)

2.0 Fertilizer sector in India

Indian fertilizer Industry is world class in implementing upgraded technologies frequently and achieving best energy efficient levels in the world. India became the third largest fertilizer producer in the world in 2016. Globally, India ranks third in consumption of fertilizers. The global fertilizer production was 245.77 million tonnes in 2015[3] . The total production of fertilizers in India for 2015-16 was 36.56 million tonnes[4] contributing to 14.87% of world's fertilizer production. The production of urea and ammonia in India during 2015-16 was 24.47 million tonnes and 11.50 million tonnes respectively.

The major producers of fertilizer in India are Indian Farmers Fertiliser Cooperative (IFFCO) and National Fertilizers Limited (NFL), having total installed capacity of approximately 6.92 million tonnes of urea. The total fertilizer production in the year 2014-15 was 33.86 million tonnes. The production in 2015-16 was 36.56 million tones, which is almost 1.2 times the production level in 2001-02 which was 29.18 million tonnes. The main output of fertilizer sector is urea which is used in agriculture for enhancing the productivity of the agriculture sector. The fertilizer production in India had a compounded average growth rate of 2.65% during 2007-2015.

In 2016, India had 30 large scale urea plants, 21 plants that produce DAP (Di-Ammonium Phosphate) and complex fertilizers and two Ammonium Sulphate production plants. The re-assessed capacity of urea, DAP & Complex fertilizers is 20.75 million tonnes and 14.6 million tonnes respectively.

Highlights Of Fertilizer Sector

- India is the third largest manufacturer of fertilizer in the world
- Annual production of fertilizer in India was 36.56 million tonnes in 2015-16 (Ministry of Chemical and Fertilizers)
- Identified as one of the eight core sectors by Ministry of commerce

3 Food and Agriculture Organization of the United Nations; http://www.fao.org/3/a-i6895e.pdf

4 Annual report 2016-17Ministry of Fertilizer and Chemicals (Indian Fertilizer Scenario), GoI

Fertilizer Production (million Tonnes)				
Year	Urea	DAP	COMPLEX FERTILIZER	TOTAL (Urea + DAP Complex Fertilizer)
2007-08	19.857	4.212	5.85	29.919
2008-09	19.922	2.993	6.848	29.763
2009-10	21.112	4.247	8.038	33.397
2010-11	21.880	3.537	8.727	34.144
2011-12	21.984	3.963	7.77	33.717
2012-13	22.575	3.647	6.18	32.402
2013-14	22.715	3.611	6.913	33.239
2014-15	22.585	3.444	7.832	33.861
2015-16	24.475	3.787	8.301	36.563
2016-17	24.201	4.333	7.924	36.458
2017-18	24.026	4.654	8.239	36.919

Table 2: Fertilizer Sector – Production and Growth[5]

2.1 Sectoral contribution to Country's Economic value

Fertilizer sector plays a significant role in India's economy by improving the agriculture sector. The production data for fertilizer sector (urea production) from 2007-2015 is given in Table 3, showing a compounded annual growth rate being 2.65%[6].

The above table does not consider the equivalent production of caustic soda from hydrogen which is considered in PAT. The calculated energy intensity considers the energy consumption of both CPP and non-CPP based plants in the sector.

Fertilizer Production (million Tonnes)		
Sl. No	Year	Urea
1	2007-08	19.85
2	2008-09	19.92
3	2009-10	21.11
4	2010-11	21.88
5	2011-12	21.98
6	2012-13	22.57
7	2013-14	22.71
8	2014-15	22.58
9	2015-16	24.47
10	2019-20	27.17
11	2024-25	30.97
12	2029-30	35.30
CAGR (%)		**2.65**

Table 3: Fertilizer Sector Growth[7]

5 Department of Fertilizer, Ministry of Chemicals & Fertilizers, GoI
6 Production data from Department of Fertilizer, GoI
7 Fertilizer scenario 2015, Dept. of Fertilizers, GoI

Financial Year	Total Energy Consumption of India	Gross Domestic Product (GDP)	Energy Intensity
	million TOE	Billion USD	TOE/ million USD
2008	427	1,187	360
2009	453	1,324	342
2010	512	1,657	309
Average Baseline[8]	464	1,389	334
2015	659	2,102[10]	313
2020	1018[11]	3,018	337
2025	1211[12]	4,233	286
2030	1440[7]	5,937[14]	243

Table 4: India's energy intensity

Financial Year	Total Production[15]	Total Energy Consumption	Gross Domestic Product (GDP)	Energy Intensity
	million Tonnes	million TOE	Billion USD	TOE/ million USD
Average Baseline	20.05	8.20	1,389	5.90
2015	21.13	7.82	2,102	3.71
2020	24.08	8.33	3,018	2.76
2025	27.44	8.93	4,233	2.11
2030	31.27	9.63	5,937	1.62

Table 5: Fertilizer sector- energy intensity

The contribution of DCs to overall energy intensity of India is 1.76% for baseline year. Fertilizer sector has achieved 0.78 million TOE savings under PAT cycle-I. The contribution of this energy savings to overall energy intensity of India is 0.12 % for assessment year.

Fertilizer sector Energy intensity contribution in baseline year and assessment year was **1.77%** and **1.19%** respectively.

8 Average of production from 2007-2010

9 BP Statistical Review of World Energy 2016

10 GDP from World Bank GDP for India – Up to 2015

11 India Energy Outlook, Year 2015 - IEA

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

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

15 Total production of DCs under PAT

3.0 Process, Technologies and energy consumption trend of the sector

Fertilizers contain three basic nutrients: nitrogen, phosphorus and potassium. Nitrogen is contained in nitrogenous fertilizers like urea and ammonia fertilizers (like ammonium sulphate). Then there are complex fertilizers that combine all three nutrients (N, P & K). Phosphorus is contained in phosphatic fertilizers (super phosphate) and potassium is contained in straight potassic fertilizer (like sulphate of potash).

Out of the three fertilizer types, production of ammonia (for nitrogenous fertilizer) is the most energy intensive process. The most important step in that process is the production of hydrogen followed by reaction with nitrogen. There are number of processes for hydrogen production which differ primarily in the type of feedstock used.

Naphtha and natural gas (NG) are the most commonly used feed stocks in India. But recently natural gas is preferred as feedstock since it is less energy intensive to produce hydrogen from NG as compared to naphtha. Also NG has more hydrogen per unit weight as compared to naptha and is easy to produce due to its light weight.

Reforming

In this process natural gas (CH_4) is mixed with steam and air to produce a mixture of hydrogen gas (H_2), carbon monoxide (CO) and carbon dioxide (CO_2). The product obtained is called synthesis gas or Syngas. Waste heat is used for preheating of feedstock and steam production; and part of the methane is burnt to generate energy required to drive the reaction.

CO conversion

CO is further converted to CO_2 and H_2 using the water gas shift reaction. This reduces the concentration of CO by converting it into CO_2.

CO_2 removal

CO_2 is removed from Syngas, in CO_2 stripper, by Benfield method or MDEA (methyl di-ethanol amine) process. The removed CO_2 is given to the urea plant or to vent and majority of condensate is returned to the top of the CO_2 stripper.

Methanation

Since CO and CO_2 are poisonous for the ammonia synthesis catalyst, they are further reduced by converting them into methane.

Ammonia Synthesis

After CO and CO_2 is removed from the gas mixture ammonia (NH3) is obtained by synthesis reaction. Syngas is compressed to a pressure of about 140 ata and a temperature of 450°C.

Ammonia is used to produce other nitrogenous fertilizers. Ammonia can be used in a reaction with carbon dioxide to produce urea. Ammonium nitrate can be produced through the combination of ammonia and nitric acid adding further energy in form of steam and electricity. Other fertilizer types produced on the base of ammonia include calcium ammonium nitrate (ammonium nitrate mixed with ground dolomite) and NP or NPK compound fertilizers.

Urea production

Ammonia and carbon dioxide are fed to the synthesis reactor which operates around 180-210oC and 150 ata pressure. The reaction mixture containing ammonia, ammonium carbamate and urea is first stripped of the ammonia and the resultant solution passes through a number of decomposers operating at progressively reduced pressures. Here, the unconverted carbamate is decomposed back to ammonia and carbon dioxide and recycled to the reactor.

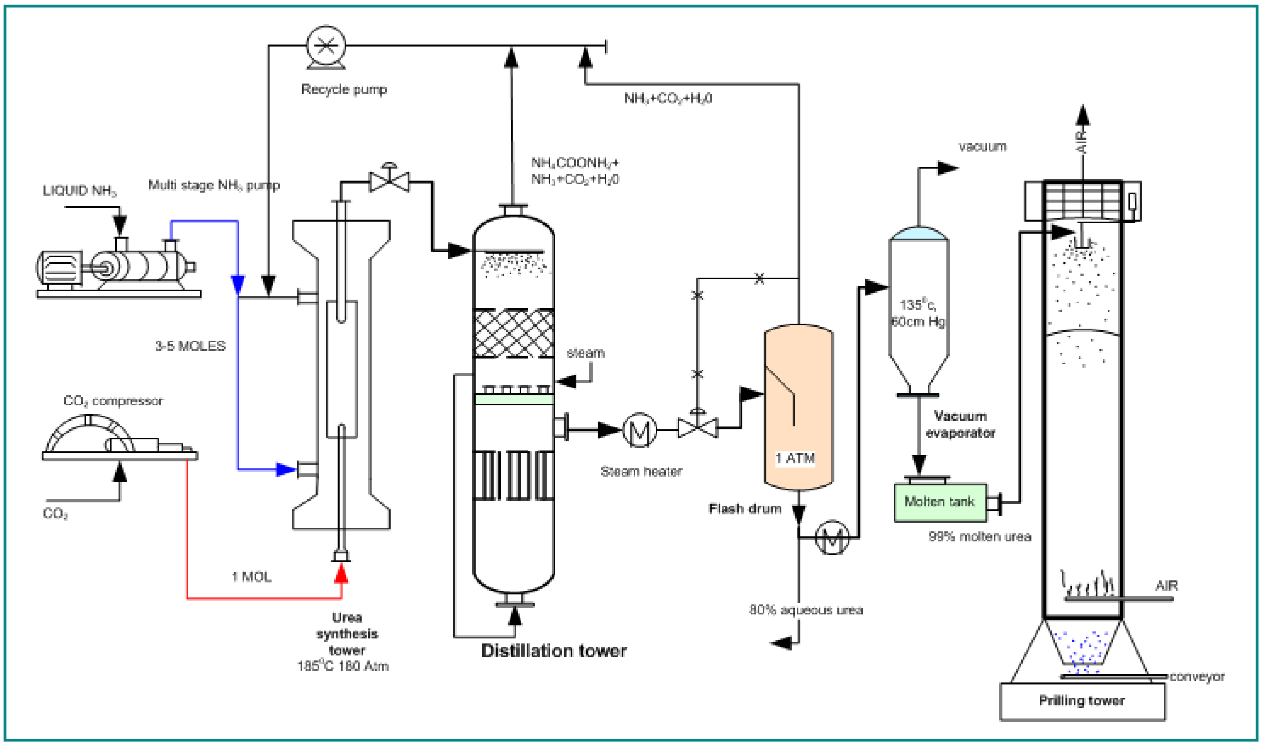

Figure 1: Urea manufacturing process

The urea solution is concentrated by evaporation or crystallisation, and the crystals are melted to yield pure urea in the form of pills or granules. Prills are made by spraying molten urea from the top of a high tower through a counter current air stream. Granular urea is formed by spraying molten urea into a mixture of dried urea particles and fines in a rotating drum.

Urea processes fall into two categories: external solutions recycle system; and internal solution stripping systems. In the former, energy is saved by high carbon dioxide conversion rates while the latter reduces net energy requirements by optimising heat recovery.

4.0 Methodology adopted for the project

The activities were initiated with the collection of sector specific data from Bureau of Energy Efficiency (BEE). In addition, data was also collected through secondary research. Data analysis was conducted to assess the impact of PAT Cycle – I on energy intensity in the BAU v/s PAT scenario, GDP of the country, trend analysis for energy efficiency, and quantification of energy saving in terms of TOE, and coal saving. Feedback was also collected from DCs on benefits and the challenges experienced through the PAT scheme.

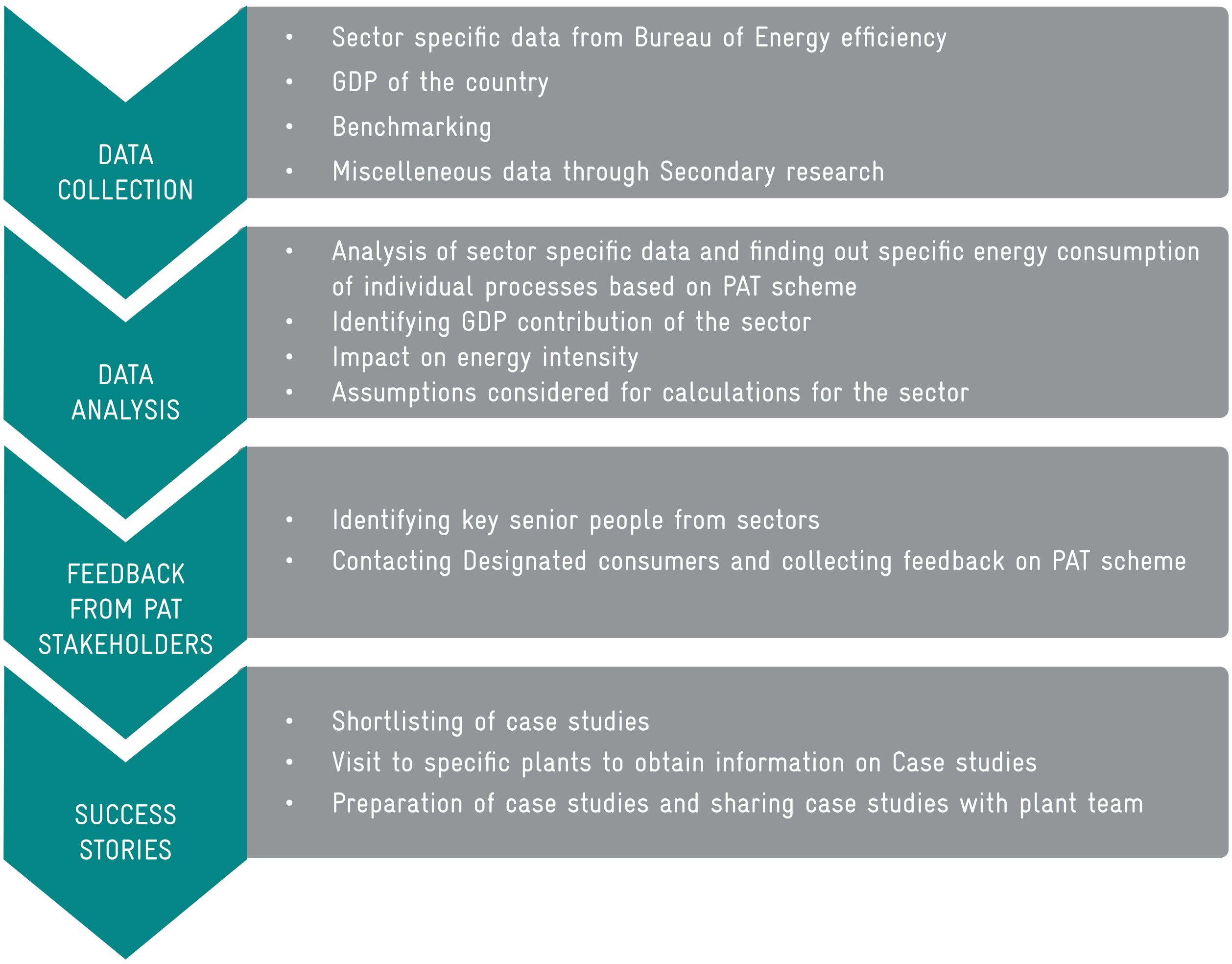

Figure 2: Methodology followed for Impact assessment of PAT cycle-I

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

5.0 PAT cycle-I and its impact on fertilizer sector

PAT scheme's primary goal is to reduce energy consumption by assigning time bound targets to the DCs. Any gain or shortfall in meeting the target is offset by trading ESCerts; where one ESCert is equivalent to one metric tonne of oil equivalent (MTOE) of energy saving. This scheme is regulated by Bureau of Energy Efficiency (BEE). The existing power exchange facilitate trading of ESCerts among DCs.

PAT Cycle – I was started in 2012. The baseline considered was from financial years 2007-08 to 2009-10; wherein a financial year corresponds to time span of 1st April of one year to 31st March of the next year. The average value of specific energy consumed by the plant was taken for three years. The minimum threshold for annual energy consumption in MTOE varies from sector to sector. For declaring a plant as designated consumer in the fertilizer sector, the threshold annual energy consumption level is 30,000 MTOE.

Under PAT cycle-1, 29 fertilizer plants were listed as DCs and were mandated to reduce their specific energy consumption as per the target given. Among the 29 DCs, there are 28 urea producing plant and 1 ammonia plant. The total reported energy consumption of these designated consumers was about 8.2 million TOE in the baseline period. These DCs were given SEC target reduction of 5.83% and energy saving target of 0.478 million TOE and this was 7.15% of the total national energy saving target under PAT cycle- I. Subsequently, after the completion of PAT cycle I, the 37 units for fertilizer sector were notified as DCs with their overall energy consumption as 8.26 million TOE in PAT cycle-II. The sector got the average target of 5.4% which is around 0.44 million TOE energy reduction.

5.1 Impact of PAT cycle-I

Fertilizer sector has achieved 0.78 million TOE in comparison to the target of 0.478 million TOE. This achievement has estimated GHG emission reduction of 0.93 million tonnes of CO_2 equivalent. The results of PAT cycle-I in Fertilizer sector are summarized in Figure 33.

Figure 3: Savings achieved by PAT in Fertilizer

The savings are attributed to a number of measures adopted by the DCs. Some of the DCs have implemented short term measures with minimal investment, others have opted for medium and long-term measures requiring considerable investment. Investment of INR 87.33 billion was reported by 83% of DCs in the sector. The emissions reduction due to PAT cycle – I and contribution of these emissions are mentioned in Table 6. This value considers the emissions of fossil fuels only and is based on the fuel mix in the sector.

Parameter	Value
Reduction of CO_2 emission due to implementation of PAT cycle-I (All sectors)	31 million Tonnes of CO_2 equivalent
Reduction of CO_2 emission due to implementation of PAT cycle-I in fertilizer sector	0.93 million Tonnes of CO_2 equivalent
Contribution to CO_2 emission reduction in overall PAT cycle-I	3%

Table 6: Reduction in CO_2 emissions from the PAT cycle-I

5.2 Energy Scenario at Business as usual (BAU) vis-à-vis with PAT impact

This 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.	29
Baseline energy consumption in PAT cycle-I for the sector	million TOE	8.2
Energy reduction target for the sector	million TOE	0.478
Energy savings achieved in PAT cycle-I for the sector	million TOE	0.780
Energy savings achieved in excess of target	million T CO_2	0.302
Reduction in GHG Emissions in cycle-I for the Sector	million TOE	0.93
Cumulative energy savings of PAT Impact till 2030[16] (over BAU)	million T CO_2	12.95

Table 7: Achievements of Fertilizer sector in PAT cycle-I and projection till 2030

The calculation of greenhouse gas emissions for PAT cycle-I had been done based on the fuel mix of the fertilizer sector under PAT cycle-I.

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 reduction in specific energy consumption in the baseline year from 2007 – 08, 2008 – 09 and 2009 – 10, has been calculated and considered as Business as Usual scenario (BAU). This reduction in specific energy consumption is used to project the reduction by the sector till 2030.

Considering the reduction in specific energy consumption during the baseline year and the assessment year, the comparison is made to analyze the energy consumption with PAT and the BAU scenario. The graphical representation of market transformation of the fertilizer industry due to implementation of PAT scheme is shown below:

16 Difference of energy consumption between PAT and Business as Usual scenario(BAU)

The graphs in this section show specific energy consumption, and energy consumption for Business as usual and impact of PAT, projected to 2030. The reduction from baseline to assessment year of PAT is the reduction in specific energy consumption for PAT cycle-I. Since the achievement of specific energy consumption targets is considered to be achieved after PAT cycle-II, the specific energy reduction is lesser than PAT cycle-I. Figure 4 & 5 shows the projection till 2030 for specific energy consumption, energy consumption for fertilizer sector.

During PAT cycle-I, four fuel oil-based plants were converted to natural gas-based plants. This change over of feedstock to natural gas resulted in higher energy saving. Since it is a onetime dispensation, the four plants have been excluded while working out projections of energy reduction.

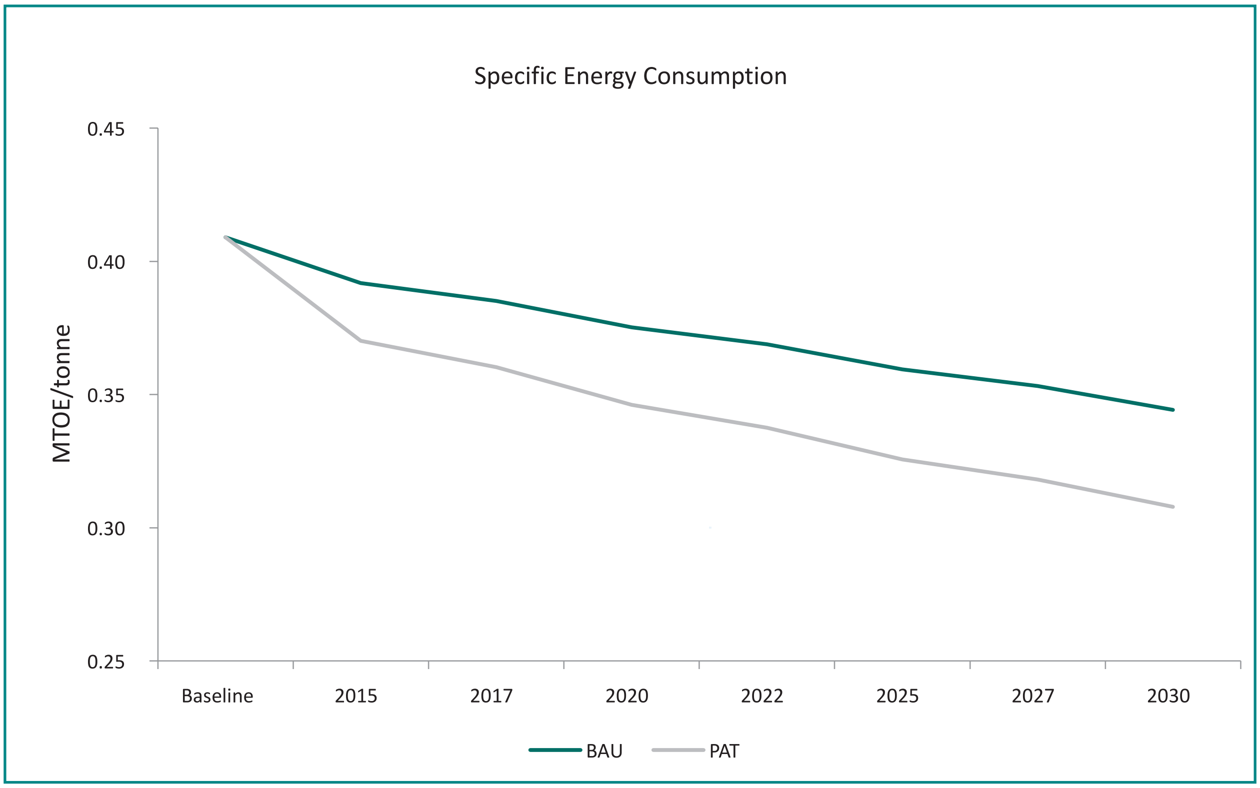

Figure 4: SEC trend BAU v/s PAT

The total energy consumption trend is also calculated and graphically represented to give a better idea of the trend for with and without (Business as usual) PAT scenario. Following is the graphical representation of the energy consumption by the sector:

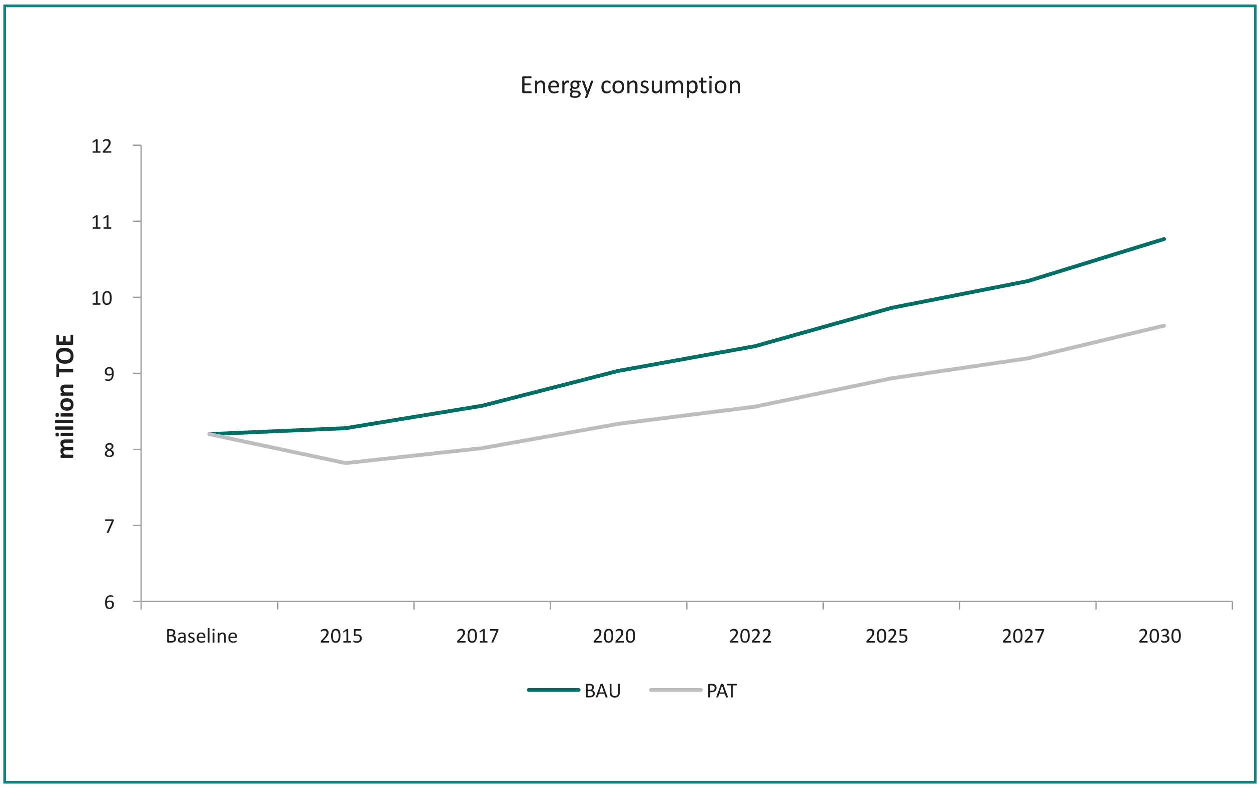

Figure 5: Total Energy Consumption Trend – BAU v/s PAT

The total energy consumption for Fertilizer sector in the year 2030 without the impact of PAT is estimated to be **10.77 million TOE**, which may reduce to **9.63 million TOE** considering the impact of PAT.

The graph in Figure 5 indicates that the PAT scheme would have positive benefit on the sector and would help in reducing the energy consumption additionally by 1.136 million TOE over the BAU in 2030 and collective energy benefits for all years (2015-2030) would be 12.95 million TOE.

Year	GDP	Business as usual	With PAT
	Billion USD	Energy Intensity	Energy Intensity
		TOE/million USD	TOE/million USD
Baseline	1,389	5.90	5.90
2015	2,102[18]	3.94	3.71
2020	3,018	2.99	2.76
2025	4,233	2.33	2.11
2030	5,937[19]	1.81	1.62

Table 8: Energy intensity with PAT and BAU for Fertilizer

18 GDP from World Bank GDP for India – Up to 2015

19 GDP values calculated based on CAGR value of 7.5% till 2020 and 7% between 2020 and 2030. Same assumptions have been considered in India Energy Outlook, Year 2015 – IEA

Figure 6: A view of Fertilizer plant

Assumptions considered for BAU Vs PAT calculation

Specific Energy Consumption

- The SEC of the sector has been calculated by considering the total production of the sector and the total energy consumption in the sector, and hence may not represent the actual SEC of any particular sub-sector/ product/ process.

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 specific energy consumption in the baseline year from 2007 – 08, 2008 – 09 and 2009 – 10, has been calculated and the same is projected till the year 2030 to get the BAU scenario.

With PAT scenario:

- The actual energy saving achieved in the PAT Cycle I is taken for the assessment year 2014 – 15.
- It has been assumed that the plants meet the target allotted to them till the years 2030.
- The target for the subsequent PAT cycles is calculated based on the current trend of reduction in target between PAT Cycle I and II.
- It has been considered that 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.
- It has also been considered that some breakthrough technological advancement might provide further reduction potential in the sector.
- The projection for production has been made based on the existing DCs under PAT cycle-I, including both NG plants and plants that switched over to NG during PAT cycle- I.

5.3 Fertilizer sector specific data analysis of PAT cycle-I

The following section contains the details on the various aspects of energy efficiency in Fertilizer sector based on the data submitted by the designated consumers under the PAT Scheme. During PAT cycle-I, only ammonia/urea producing plants were considered. There are 28 DCs producing ammonia/urea and one DC producing ammonia only. Total installed (Revamped) capacity of urea product for 28 DCs is 19.2 million MT and ammonia product for one DC is 0.327 million MT.

Year	GDP	Installed capacity (million MT)		Actual Production (million MT)	
		BY	AY	BY	AY
Urea	28	19.2	19.2	20.544	21.485
Ammonia	1	0.327	0.327	0.137	0.028

Table 9: Capacity and Production of the sector[20]

There is an increase of 4.5% in actual production of urea, due to a number of reasons like revamps for capacity enhancement and energy reduction, increased capacity utilization, availability of raw feedstock and Government policy.

Another significant change in the sector is the use of natural gas as feedstock instead of fuel oil and naphtha. This increased the efficiency of the plants by a good margin. Some of the plants were re-vamped to make use of natural gas as the feedstock. The use of NG, as feedstock, increased by almost 1.3 times in the AY as compared to BY.

20 Data from PAT cycle-I

Feedstock used	Total Consumption		
	Unit	BY	AY
NG	Million SCM	10,954	14,146
Naphtha	MT	1,649,220	233,530
Fuel oil	MT	1,422,969	122,756

Table 10: Feedstock consumption during BY and AY[21]

The feedstock of four plants was switched over from fuel oil to natural gas during the PAT cycle-I period. This revamping of the units to accommodate the use of NG as feedstock brought about a high reduction in SEC.

Parameter	Unit	Baseline year		Assessment year	
		Best	Average	Best	Average
Electrical SEC	MWh/MT	0.023	0.092	0.026	0.092
Thermal SEC	Gcal/MT	5.167	7.35	5.131	6.831
Overall SEC	Gcal/MT	5.171	7.354	5.135	6.836

Table 11: Average and Best SEC values in PAT cycle-I

Table 11 gives a comparison of specific the energy consumption of urea plants in PAT cycle-I between baseline and assessment year.

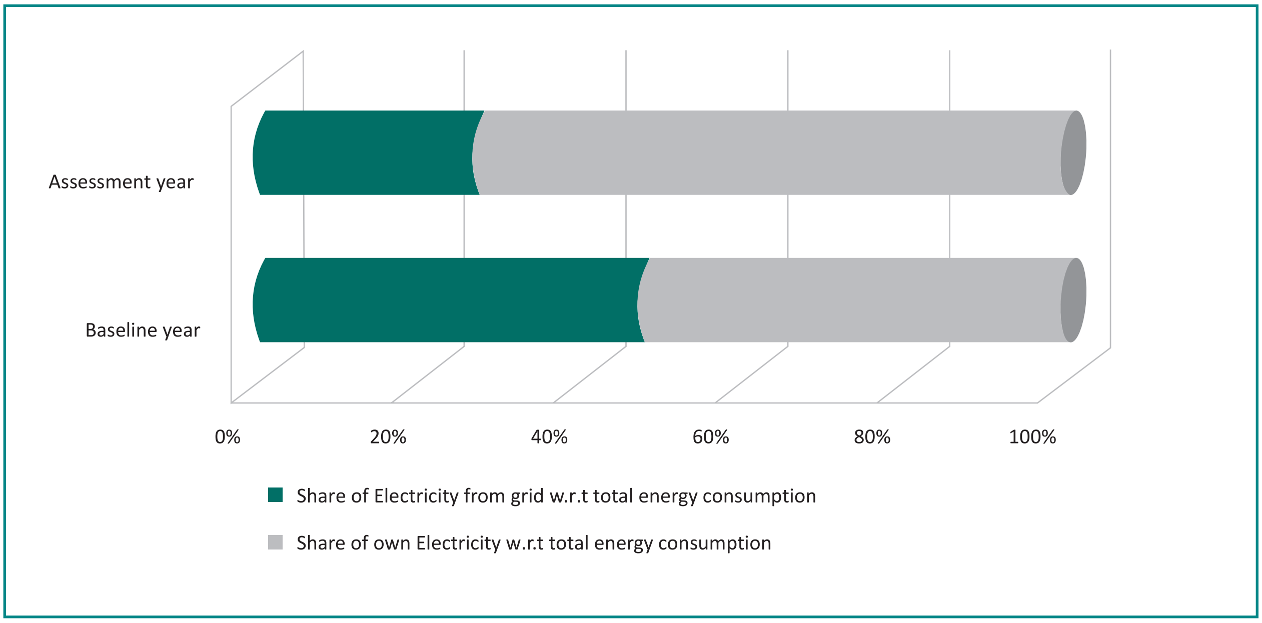

Figure 7: Share of electricity from grid for Fertilizer sector in BY and AY

The share of electricity generated in-house in total energy consumed increased by 39% between baseline year and assessment year.

21 Data from PAT cycle-I

6.0 Benchmarking in Fertilizer Sector

Few Indian gas based plants having capacity >3000 TPD of urea, based on natural gas feedstock, have specific energy consumption approaching international standards. Some older plants with 40 to 50 years vintage have low capacities (around 1000 TPD/urea) may not be able to achieve lower energy standards. However, with the progressive installation of new gas based plants employing latest technology and phasing out of some older inefficient plants, there is potential for energy efficiency improvement in Indian fertilizer sector.

The most efficient plant in India, among PAT cycle-I DCs, has an SEC of 5.17 Gcal/MT of urea.

Product	SEC (Gcal/MT)		
	India (average)	India (best)	World best
Urea	5.93	5.164	5.00[22]
Ammonia	8.33[20]	7.098	6.88[23]

Table 12: Benchmarking – Fertilizer Sector

22 PAT pulse May 2016 edition

23 Best Available Technology value taken from Global-Industrial-Energy-Efficiency-Benchmarking, UNIDO

7.0 List of major energy saving opportunities in the sector

A list of major energy saving opportunities in the sector have been identified and listed in Table 14. 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)
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	Technology	Co-Benefits	Readiness Level (TRL)	Payback
1	Centrifugal compressors installation	C, E	TRL-5	PB5
2	Energy monitoring and management system	C, D, E	TRL-3	PB8
3	Variable frequency drive	C, E	TRL-5	PB3
4	Improvement in reformer tubes material	P,Q,C	TRL-5	PB8
5	Changing from axial flow to radial flow in CO shift converter	P,Q,C,E	TRL-4	PB8
6	Install purge gas recovery unit in Ammonia synthesis	P,Q,C,S,E	TRL-5	PB8
7	Improving conversion efficiency in Urea reactor	P,Q,C,S,E	TRL-5	PB5
8	Installation of high efficiency turbine for air blower in sulphuric acid plant	C,E	TRL-5	PB3
9	Waste heat recovery from compressors	C,E,M	TRL-5	PB3
10	Heat pump for chillers	P,C,E,M	TRL-5	PB3
11	Waste Heat recovery from synthesis gas	C, E	TRL-5	PB3
12	Converter sensible heat recovery system	C, E	TRL-5	PB3
13	Waste Heat recovery from flue gas by using recuperator and /or Vapour absorption system or ORC technology	C, E	TRL-5	PB5
14	Installation of VAM system for CO_2 cooler in urea plant	C, E	TRL-5	PB3
15	Recover Ammonia from off gases of synthesis loop	C, E	TRL-5	PB3
16	Use of flash steam generated in Steam condensate tank as motive fluid in booster ejector in Urea Plant	C,E	TRL-5	PB5
17	Reducing load of CO_2 Blower by closing anti-surge valve in CO_2 removal section of Ammonia plant	C,E	TRL-5	PB5
18	Energy efficiency in electrical equipment (EE motors & LEDs)	C,E	TRL-5	PB3
19	Cooling tower up-gradation (Retrofitting of CT & installation of VFDs)	C,E	TRL-5	PB5

Table 13: List of Energy saving technologies

8.0 Success stories – Case Studies in Fertilizer sector

8.1 Case Study No. 1 : Installation of Vortex Mixer in Urea reactor

Introduction

Nagarjuna Fertilizers and Chemicals Limited (NFCL) is engaged in the manufacture of Urea Fertilizer in the complex located at Kakinada, East Coast of Andhra Pradesh. NFCL is the Flagship Company of the Nagarjuna Group, a well-diversified and fast-growing group in India. It is the first natural gas based fertilizer complex in South India. The plant is located around 5 Km off North-East of Kakinada town on barren land, which is around 1 km from Kakinada Port.

NFCL undertook an expansion in 1995 with identical capacity unit-2 as the original plant was installed but based on naphtha as feedstock. Plant operations were completely switched over to full NG mode in the year 2009 subsequent to commencement of RIL NG supply. Both the units were revamped during Sept 2009. Ammonia unit-1 was installed in year 1992 and unit-2 was installed in year 1998 with installed capacities of 900 metric ton per day (MTPD) each. Both ammonia units are followed by individual urea units, i.e. Urea-1& Urea-2 each of 1500MTPD urea capacity initially. The raw material used includes natural gas, water and air. Source of water is Godavari River and power is produced within plant by 3 nos. gas turbines i.e. one 21MW and two 6.7MW generation capacities. Annual production capacity of Urea is 1.6 million MT.

The units have been revamped over the years and subsequently urea production capacity increased to 2325 MTPD and 2281 MTPD for unit-1 and unit-2 respectively. In past, the plant has under taken various projects for energy improvement out of which one major is the replacement of sieve trays with Casale trays in urea reactor followed by installation of Vortex Mixer in Urea reactor (unit-2 only) bottom to improve the conversion in the reactor. Vortex mixer is an excellent step in improving the urea reactor yield and thereby anticipated reduction in specific steam consumption by 35 kg medium pressure steam (24ata) per ton of Urea in unit-2.

Conventional system of operation:

Urea is produced by synthesis of liquid ammonia and gaseous carbon di-oxide. In the reactor the ammonia and carbon di-oxide react to form ammonium carbamate, a portion of which decomposes (dehydrates) in urea reactor to form urea and water. The reactions are as follows:

Reaction-1: 2NH3 + CO_2 --------> NH2COONH4 + 37.64 kcal/kmol

(Ammonium Carbamate)

Reaction-2: NH2COONH4 ------> NH2CONH2 + H2O – 6.32 kcal/kmol

(Urea)

In synthesis conditions (T=188^{0}C and P=156 bar) the first reaction occurs rapidly and completed, the second reaction occurs slowly and is the rate governing reaction. The molar ratio of Ammonia to Carbon di-oxide is maintained around 3.3 to 3.6 making ammonia as the excess reagent. The urea reactor is a plug flow reactor with 14 Casale trays installed inside the reactor.

Before installation of Vortex Mixer, compressed CO_2 at 160ata was feed inside the reactor from bottom via a sparger pipe which is a vertical pipe with holes on its lateral surface; liquid ammonia was pumped inside reactor from bottom at 240 ata through a similar sparger pipe. Liquid ammonia line also carries recycled carbamate feed through an ejector. In steady state, CO_2 bubbles out of the sparger in liquid ammonia pool at the bottom of reactor. The conversion in reaction-1 was highly dependent on bubble size and contact time between CO_2 bubble and liquid ammonia. As the liquid-gas mixture travels up the reactor, second reaction takes place with the production of urea. Urea is further recovered from carbamate-urea mixture and purified in various steps to get 99.7% to 99.8% urea.

Requirement of further improvement

The reaction-2 is a slow endothermic reaction whereas the reaction-1 is exothermic in nature. Reaction-2 takes up heat from system which was evolved due to reaction-1; therefore the following points are important for further improvement in product yield:

- The forward reaction involves volume increase and hence lower pressure favour it,
- The reaction is accompanied by absorption of heat; therefore, the Vortex mixture is very important because the reaction heat is involved,
- The reaction is directly proportional to mixing of the fluid i.e. Contact surface area,
- However, the overall reaction is plug flow but internal mixing act as a bank of CSTR (continuous stirred tank Reactor).

Description of the project

The Vortex Mixer: The basic design is similar to a gas-liquid reactor with a rising unidirectional phase movement. Pipes for introducing reactants (i.e. carbon di oxide and ammonia) are connected to inlet a mixer which is located in the lower part of the body and the axial outlet pipe of which is directed either towards the bottom of the reactor or upwards, and which is equipped with a diffuser. The mixer consists either of a coaxial tube and of one or more consecutively connected coaxial vortex chambers with tangential inlet pipes, or only of two or more vortex chambers. The tangential pipes ensure an identical direction of rotation of the flow in vortex mixer. At least one of the tangential pipes is inclined in the opposite direction of the outlet opening in the axial pipe. The mixer, with the outlet pipe directed upwards, is located within a cylindrical shell which is concentric to the body of the reactor. The result is an increase in the intensity of dispersion of the interacting phases and in the uniformity of dispersion of the reactants in the two-phase flow is achieved.

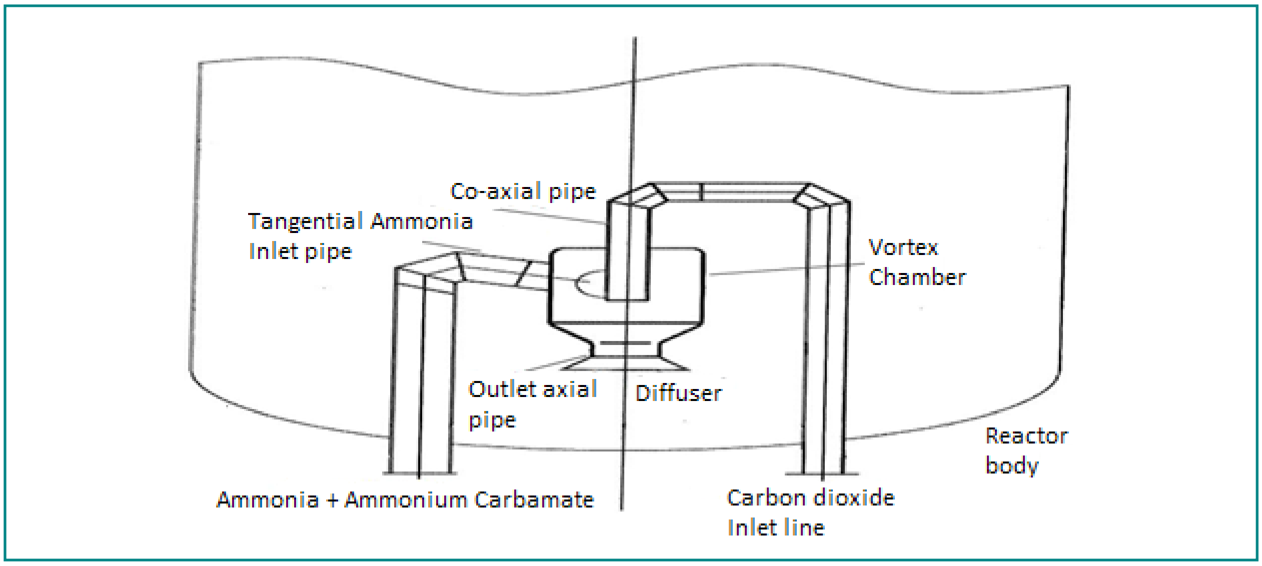

Figure 8: Vortex mixer in Urea reactor

A hollow conic surface is installed below the pipe for better dispersion of reaction mixture. ammonium carbamate outlet is facing the reactor bottom with its open basis, a cyclonic ejector installed under the conic surface, having a tangential pipe connected to one of the inlet pipes for liquid ammonia. A nozzle directed towards the bottom of the reactor, and a coaxial pipe located inside an ejector, the top end of the pipe is connected to the space of the hollow conic surface, its lower end is located at the level of the nozzle outlet over the distribution device for supply of a carbon dioxide. The present design of a reactor is characterized by non-uniform distribution of carbon dioxide in the volume of liquid because of separate inlet of Ammonia & Carbon dioxide and specific design of the gas distribution device.

Lab Analysis during base case test for Vortex mixer Installation in Urea-ll

Process Samples (Before Installation)- At Urea reactor outlet									
Date	**Time**	**Unit**	**Urea**	**NH3**	**CO_2**	**H_2O**	**conversion**	**N/C**	**H/C**
8 Jul'13	11:00 to 12:15	Wt%	32.99	30.99	18.12	17.90	57.2	3.04	0.46

Process Samples (After Installation)- At Urea reactor outlet									
Date	**Time**		**Urea**	**NH_3**	**CO_2**	**H_2O**	**conversion**	**N/C**	**H/C**
26 Jun'14	15:15 to 16.30 hrs	Wt%	33.83	29.98	18.11	18.08	57.8	2.96	0.45

Process path for which technology is applicable:

This technology is applicable for urea manufacturing process where shift conversion process is used and Urea manufacturing reactor is a tray tower with bottom feed arrangement.

Timeline for the project:

The overall time for project from idea to implementation took around 2 years out of which around 6 months were for erection and commissioning. The equipment was fabricated on site and installed inside the tower during a routine shutdown of unit.

Details of mode of financing

The approximate investment for the project was INR 11 million and was financed internally as part of expansion project.

Impacts and Benefits realized:

- Savings achieved : MP steam (24 ata) 35kg/T Urea
- Investment : INR 11 Million
- Payback period : 12 months

Benefits

Parameter		Values
Energy Savings	**Rs million**	11
Annual TOE savings	TOE	1710
Investment	Rs million	11
Payback(months)	Months	12
GHG reduction	Tonne CO_2 equivalent per year	3680
Replication Potential	% of plants in the sector can opt for this technology	All Urea plants based on Tray Tower Urea reactor

Table 14: Energy Savings

Other Benefits

- Better quality of material to down lying process
- Improvement in final product output
- Reduction in steam consumption

Challenges faced during Implementation

- Shutdown required – can be done during routine shutdown of column
- Specific problems faced by plant – detailed calculations required to understand increase in specific power consumption v/s decrease in specific steam consumption.
- Downstream stripper section must be capable to handle improved yield.
- Change in operational practices – not applicable

Plant Contact details for the project	
Plant Name	Nagarjuna Fertilizers & Chemicals Limited, Kakinada, Andhra Pradesh (India)
Person to be contacted	Mr. P Chandra Mohan
Designation	General Manager – Technical Services
Contact number	+91-9676952424
Email – ID	pcmohan@nagarjunagroup.com
Address for communication	Nagarjuna Fertilizers and Chemicals Limited, Nagarjuna Road, Kakinada-533003, Andhra Pradesh, India

Table 15: Contact Details for NFCL, Kakinada

8.2 Case Study No. 2: FD Fan of Primary reformer – Turbo driven to Motor driven

Introduction

Indian Farmers Fertiliser Cooperative Limited (IFFCO) is one of India's largest cooperative societies and is wholly owned by Indian Cooperative. IFFCO Aonla located in Uttar Pradesh, is one the five-fertilizer plant of IFFCO in India. IFFCO Aonla fertilizer complex comprises of two operating units – Aonla-1 and Aonla-2 and following are the details of the plant:

Sr. No	Unit	Year Commissioned	Ammonia	Urea
1	Aonla -I	1988	1740 MTPD	2X1515MTPD
2	Aonla-II	1996	1740 MTPD	2X1515MTPD

Table 16: Installed capacity of IFFCO Aonla plant

Description of the project

The fertilizer manufacturing process is divided into Ammonia Synthesis and Urea production. Both the processes are energy intensive and require high amount of fuel and steam. The heart of Ammonia Plant is reformer, where the feedstock (Natural Gas) is converted into gaseous mixture of hydrogen, carbon monoxide, and carbon dioxide using series of reforming reaction in presence of catalyst. The gaseous mixture is sent to secondary reformer where further reforming takes places and air is also added to provide the nitrogen which is required for Ammonia synthesis. The heat from hot reformed gas is recovered through WHR boilers and introduced in the shift converters where carbon monoxide is converted into carbon dioxide and are further separated from reformer gas and is sent to urea plant. The synthesis gases is further taken to methanator, where the residual oxides of carbon are converted to methane and further is taken to synthesis gas compressor where synthesis gases are compressed and sent to ammonia converter where ammonia is formed and taken further to Urea plant for urea production.

One of the initiatives by the plant was to shift turbo driven equipment to motor driven. Following is the schematic of the Reformer section where the FD fan that supplies air to air-pre heater coil of primary reformer:

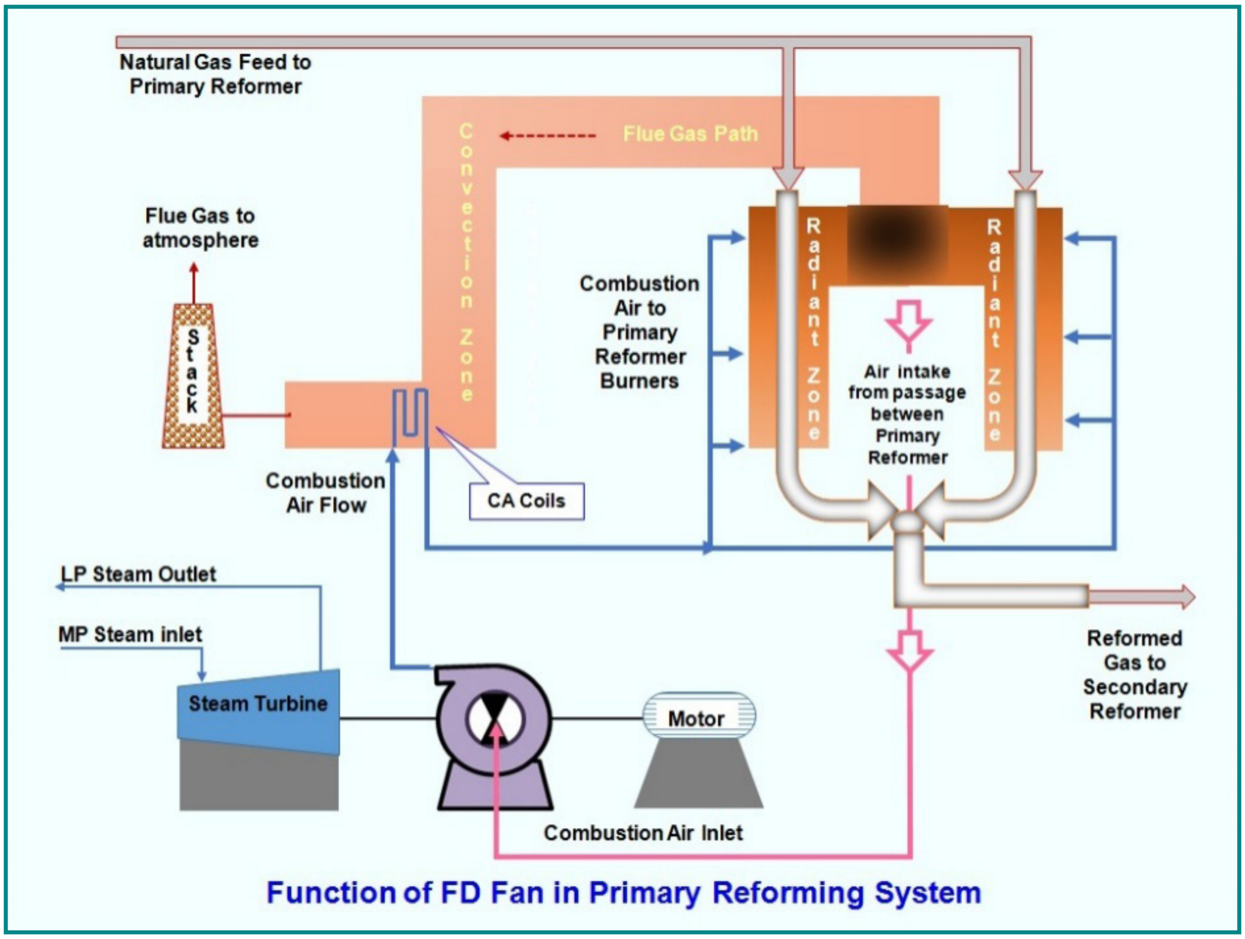

Figure 9: Primary reforming system

As shown in Figure 9, the FD fan of the reformer at the plant was provided with both turbo driven and electrical motor driven option. However, the plant was operating the FD fan with turbo drive only, where the MP steam was fed to the turbine and with motive force of steam the equipment was driven.

In IFFCO Aonla, there are two source of steam generation – a Steam Generation Plant and two captive power plants having gas turbine generators with Heat Recovery Steam Generation (HRSG) system. The plant was continually upgraded and modernised resulting which the steam requirement came down and thus, the steam generation from steam generation plant was reduced resulting in underutilisation of boiler. The lower utilisation of boiler resulted in higher cost of steam generation and on comparison with power and steam generation form - GTG &HRSG it was found that GTG and HRSG are more cost effective for meeting the energy need.

In ammonia -II, after thorough analysis, the plant found that there would be net energy saving of 0.32 Gcal/hr. Following was the basis of arriving at the decision to shift the operational philosophy of the FD Fan:

Sr. No	Particulars	Unit	Value
1	Increase in power load due to operation of motor	kW	702
2	Additional energy consumption at GTG for power generation	Gcal/hr	0.29
3	Energy of MP Steam	Gcal/hr	0.586
4	Energy used at SG for generation of steam	Gcal/hr	0.61
5	Net Energy Savings (4-2)	Gcal/hr	0.32
6	Annual Energy Savings	Gcal	2,372

Table 17: Savings due to implementation of project

Thus, based on the analysis in Table 17, it was decided to change the operational philosophy of the FD fan from turbo driven to electrical motor driven and the turbo driven drive was kept as standby.

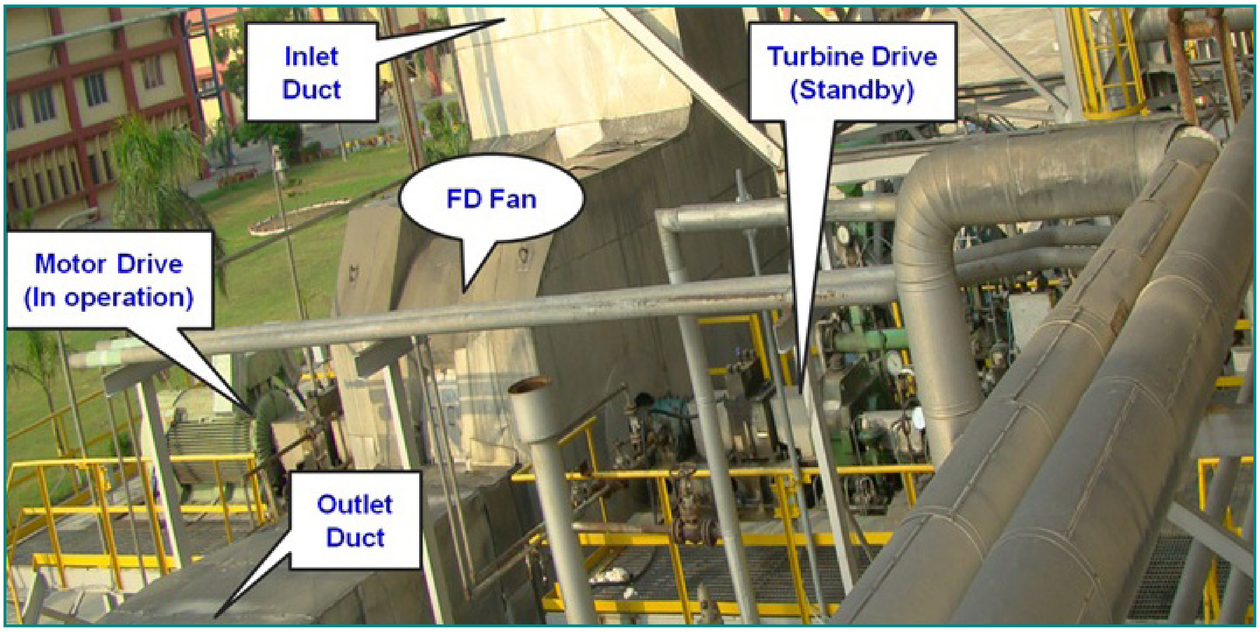

Figure 10: Motor drive in-use

The change in the operational philosophy resulted in decrease in energy consumption in SG unit and increased energy consumption at GTG system, but due to the efficiency difference and lesser cost of generation of energy in GTG resulted in overall net energy saving of the system.

Sr. No	Ammonia Plant SEC (Gcal/MT of ammonia in 2014-15)	Saving Due to measure (Gcal/MT of ammonia)	% impact on SEC
1	7.442	0.004	0.05%

Table 18: Impact on SEC due to implementation of project

There were no significant challenges faced by the plant for implementation, but for identifying such measures the plants have to undertake regular review of the steam generation and usage and energy optimisation as this can help achieve significant energy savings.

Benefits

Parameter	Units	Values
Energy savings	Rs million	6.27
Annual TOE savings	TOE	237
Investment	Rs million	NIL*
Payback(months)	Months	Immediate
GHG reduction	Tons of CO_2 per year	830
Replication Potential	% of plants in the sector can opt for this technology	60

Table 19: Energy Saving due to implementation project

The investment cost for this project is NIL since the motor was available as spare. However the investment required will be the cost of the motor.

As a result of the interventions, annual cost saving of INR 6.27million[24] was achieved due to shift from turbo driven to motor driven. As the project was identified with regular review of steam balance and energy optimisation and the electrical motor was already available, there was no significant investment required for the plant. An overall saving of 237 metric ton of oil equivalent (MTOE)[25] was obtained in this implementation. This has resulted in annual CO_2 reduction of 830 T CO_2 eq. (at 3.5 T CO2eq/MTOE).

Replicability

At present, many fertilizers plants still operate turbo driven drive for the critical equipment such as FD fan, feed water pumps, compressors, pumps, etc. However, the potential for replication of turbo drive to electrical motor need to be evaluated on case to case basis considering reliability and cost economics and then can be taken up for implementation. The potential is high in fertilizer plants where GTGs and HRSG are installed for meeting the power needs as the cost of energy to drive equipment would be relatively lesser in such cases.

Plant Contact details for the project	
Plant Name	IFFCO, Aonla
Person to be contacted	Mr. S C Gupta
Contact number	91-0581-2404001
Email – ID	sc_gupta@iffco.in
Address for communication	IFFCO Aonla, IFFCO Township, Bareilly, Uttar Pradesh 243403

Table 20: Contact Details for IFFCO Aonla

24 Calculated at composite gas price of Rs. 2645/Gcal
25 Considering energy saving of 2372 Gcal/annum

9.0 List of Technology suppliers

S No	Company Name	Technology	Website
1	Honeywell Process Solutions	Automation Solutions	https://www.honeywellprocess.com
2	Alfa Laval	Plate Heat Exchangers	https://www.alfalaval.com
3	Hindustan DOR Oliver Ltd.	Waste heat reboiler, Stripper feed cooler	https://www.hdo.in
4	Forbes Marshall	Steam Distribution Systems	https://www.forbesmarshall.com
5	FL Smidth Minerals Pvt. Ltd.	Conveying and Feeding solutions	http://www.flsmidth.com
6	Outotec	Automation, Optimisation System	http://www.outotec.com
7	ABB	Energy Efficient motors, Busbar collector systems, etc...	http://www.abb.com
8	Jhonson India	Steam and condensate systems	https://www.kadant.com
9	Lizmontagens	Refractories	https://www.lizmontagens.com
10	Atlas Copco	Waste heat recovery from compressors	https://www.atlascopco.com/en-in
11	Ingersoll Rand	Waste heat recovery from compressors	https://www.ingersollrand.co.in
12	Haldor Topsoe	Co-production solutions in Ammonia production	www.topsoe.com
13	KBR	Ammonia production optimisation and revamp	www.kbr.com
14	Thyssenkrupp AG	Industrial solutions and material services	https://www.thyssenkrupp.com
15	Casale	Revamping of plants, Vapor recovery systems	www.casale.ch
16	Linde Group	Process optimisation for Synthesis gas production	www.linde.com
17	Saipem	EPCI of pipelines and complex projects	www.saipem.com
18	Stamicarbon BV	Solutions for producing quality Urea and process operation services	www.stamicarbon.com
19	Toyo Engineering	Urea granulation solutions	www.toyo-eng.com
20	NIIK, R&D Institute of Urea	Energy efficient improvements in Urea production process	www.niik.ru

Table 21: List of key technology suppliers in Fertilizer sector

Abbreviations

Bureau of Energy Efficiency

Ministry of Power, Government of India
4th Floor, Sewa Bhawan, R. K. Puram, New Delhi – 110066 (INDIA)
T: +91 11 26766700 I F: +91 11 26178352
Email: admin@beenet.in I www.beeindia.gov.in
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