Aggregating DSM Opportunities Among Industrial Consumers at Utility Level for Low Carbon Growth

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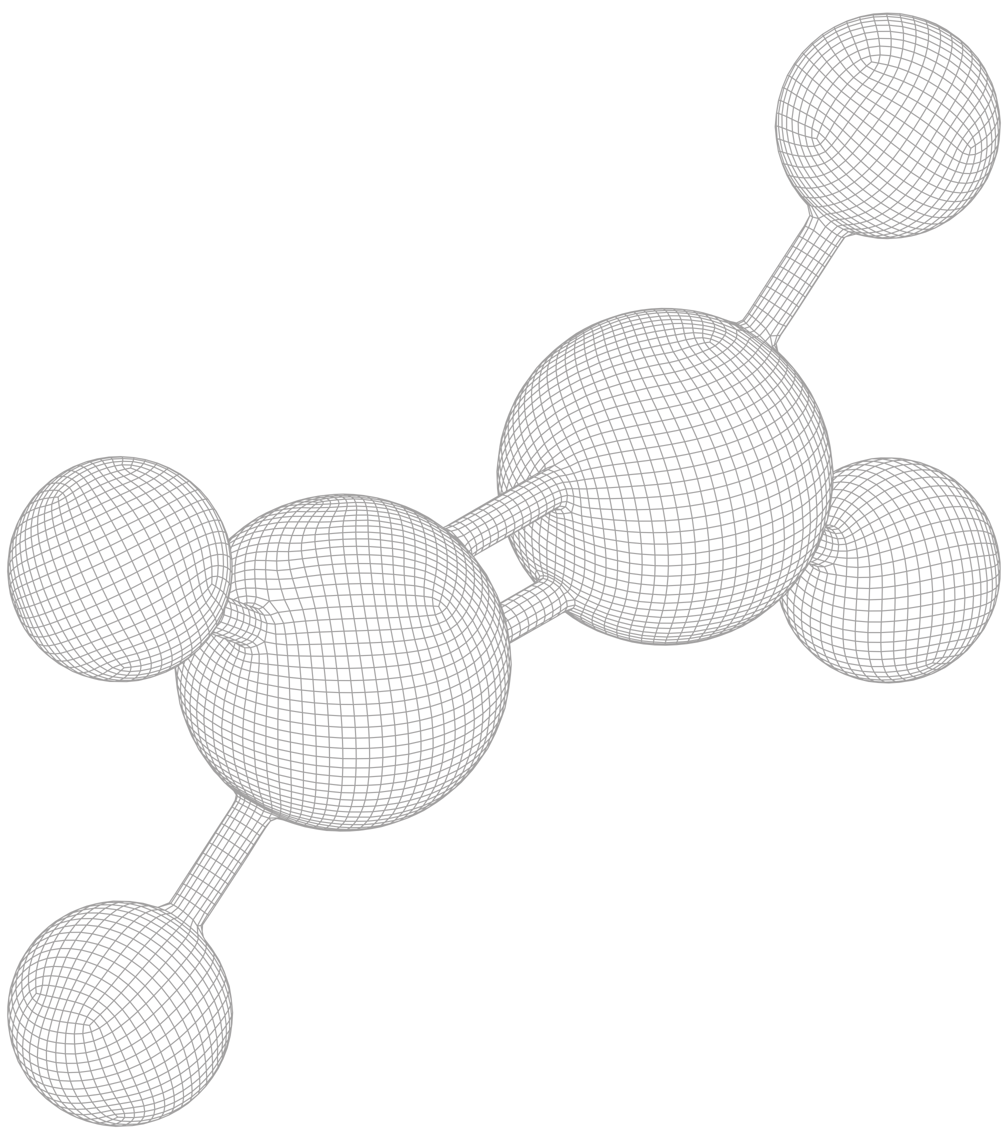

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Aggregating DSM Opportunities Among Industrial Consumers at Utility Level for Low Carbon Growth

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FOREWORD

Climate change is a global challenge. Industrial energy efficiency is one of the most cost-effective ways of mitigating GHG emissions and combating climate change. Initiatives like Perform, Achieve and Trade (PAT) for large industrial units along with cluster approach for MSMEs are helping the industry sector to improve its energy efficiency (EE); still industrial energy efficiency market in India is a sleeping giant with immense opportunities. In order to stay competitive, industries need to adopt new efficient technologies, which would reduce their operating costs.

Recognizing the enormous potential for DSM among industrial consumers, TERI, with support from MacArthur Foundation, undertook a study to explore the scope for aggregation of the DSM opportunities among SME industrial consumers in India. For the study, a partnership with the largest private sector power utility, Tata Power, was forged. About 100 SME customers were selected in consultation with Tata Power spread across Delhi, Ajmer, and Mumbai. The selection of the SMEs was followed by unit level energy assessment studies. The aggregated demand for energy efficient equipment like motors, air compressors, lighting and ceiling fans were then estimated. Based on the interactions with various stakeholders, suitable business models, which could be adopted by distribution utilities in India have been developed.

Through its extensive field work, the project team was able to identify a host of energy saving opportunities at the ground level. A few key findings:

- Most of the MSME units still use old and inefficient standard efficiency class (IE1) electric motors; about 40% of the motors have been rewound multiple times.
- There is a large potential for energy saving in the screw compressors by the adoption of variable frequency drive (VFD) or by the adoption of PMSM air compressors.
- More than half of the total number of lamps in use are of conventional type.
- Majority (99%) of the fans were of the conventional type. Very few units have adopted star-labelled ceiling fans or brushless DC (BLDC) fans.
- Cumulatively, there exists an electricity saving potential between 14–18% among the MSMEs studied, with attractive return on investment (RoI).

One of major challenges encountered during the project was to convince the SME entrepreneur to permit energy audit of their plant and share necessary data with the auditors. This was overcome with support from the utility engineers and the high credibility of TERI in energy audit field. Success stories of similar work undertaken by TERI in other parts of the country were also shared to break the ice.

In conclusion, there is huge potential to replicate such DSM studies to promote energy efficient technologies across other industrial clusters, since low-efficiency electric end-use equipment account for a major share of the total electricity consumption. At the same time, there is need to engage with existing national-level institutions (government organizations, equipment manufacturers, commercial banks, energy efficiency service providers, and NGOs) to promote the business model developed under the project.

Dr Vibha Dhawan
Director General
The Energy and Resources Institute (TERI)

PREFACE

John D. and Catherine T. MacArthur Foundation supports creative people, effective institutions, and influential networks building a more just, verdant, and peaceful world. MacArthur is placing a few big bets that truly significant progress is possible on some of the world's most pressing social challenges, including advancing global climate solutions, decreasing nuclear risk, promoting local justice reform in the US, and reducing corruption in Africa's most populous country, Nigeria. Our climate solutions activities aim to limit global warming as close as possible to the scientifically endorsed goal of 2 degrees Celsius above pre-industrial levels by significantly reducing greenhouse gas (GHG) emissions.

The three largest emitters of GHG, in order, are China, the United States, and India. India's emissions are projected to surpass China's, with 80% of projected emissions to come from sources not yet built; this provides an opportunity to make long-term, beneficial decisions now. In India, MacArthur Foundation has been partnering with TERI on several activities aimed at reducing the country's GHG emissions. This study 'Assessment for aggregating DSM opportunities at utility level amongst industrial consumers for low carbon growth' was undertaken as a sub-activity under the MacArthur-TERI partnership.

Demand-side management (DSM) is an important and integral strategy for addressing the challenges of chronic peak and energy shortages, improving access and affordability of power. The utilities are being mandated to draw up cost-effective DSM action plans. Recognising the enormous potential for DSM among SMEs, the scope for aggregation of the energy-efficient technologies among industrial SME consumers was explored under the project. It was probably the first time in a large number of detailed unit-level energy assessment studies were conducted to identify and aggregate the demand for key energy-efficient technologies like motors, air compressors, and so on, for a cluster of SMEs.

TERI found that most industrial units still use old and inefficient electric motors, and about a third of them have been rewound multiple times. Majority (about 60%) of the units were still using conventional inefficient lighting systems. Cumulatively, there exists an electricity saving potential between 14-18% with attractive return on investment. The study reveals that utilities could become demand aggregator and roll out ESCO business models, jointly with technology vendors to remove the barrier of the high initial cost of investment, which is the most significant impediment to adopting energy-efficient technologies at present. An innovative vendor-based ESCO business model was developed under the project to remove the barrier of the high initial cost of new cleaner technologies among small businesses. A workshop on the findings were organised in Delhi to disseminate the findings of the study among stakeholders.

I am confident that the efforts to develop a DSM action plan and aggregate the industrial DSM opportunities would act as a guiding document for the distribution companies to initiate DSM activities in their licensed area. Further, the study would contribute to the effective implementation of National Mission for Enhanced Energy Efficiency, which includes market-based mechanisms to enhance cost effectiveness, accelerating the shift to energy-efficient appliances/ equipment, finance demand side management programmes in all sectors by capturing future energy savings, and developing fiscal instruments to promote energy efficiency. In addition to this, the avoided generation capacity though energy efficiency will add value to India's commitment in NDCs.

Moutushi Sengupta
Country Director, India
MacArthur Foundation

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We also express our deep appreciation to all participating industries/MSME units in Delhi, Mumbai and Ajmer for their support during the field visits for conducting the assessment of energy efficiency and DSM potential and active participation during the dissemination workshops.

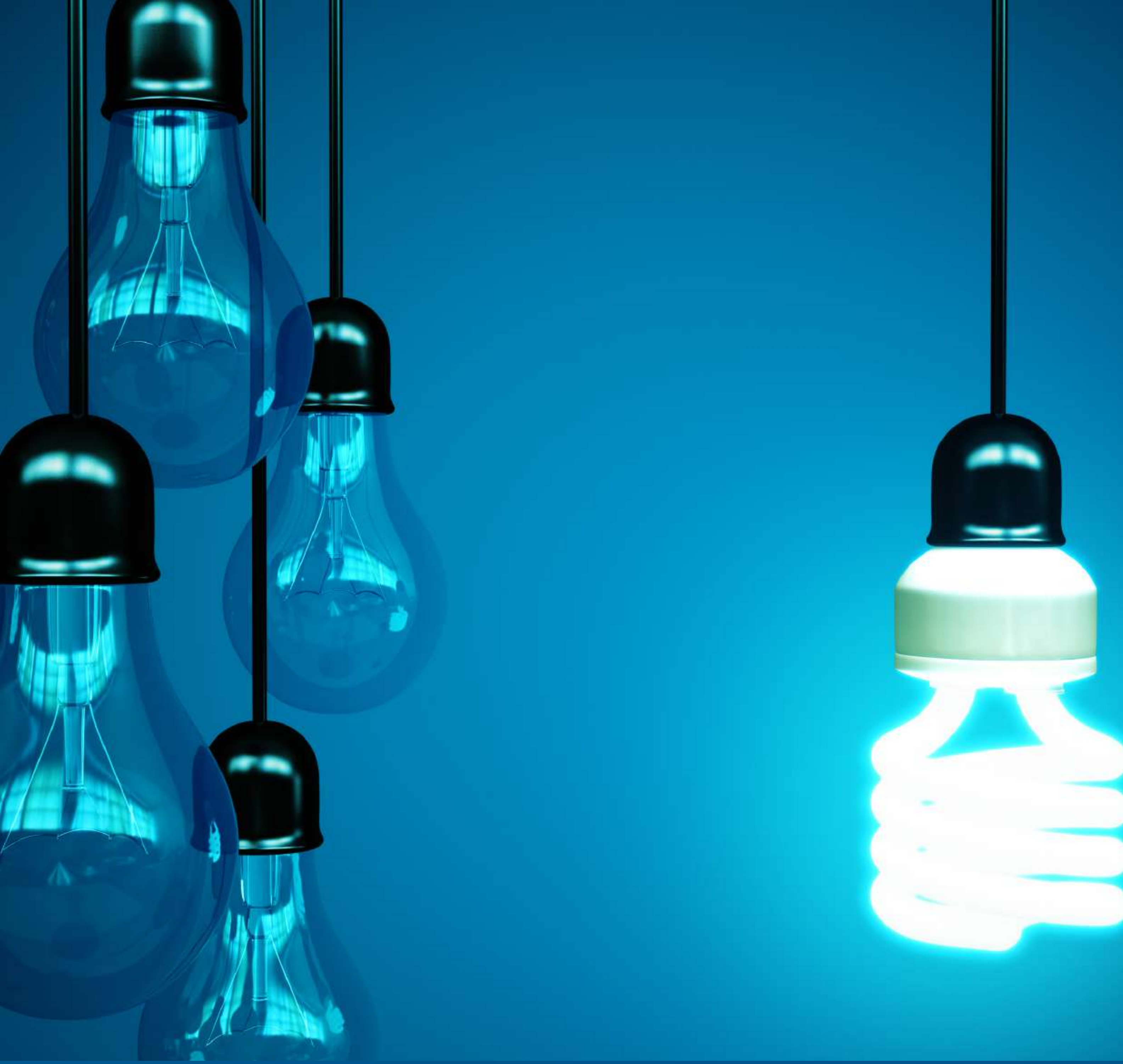
This report was funded by the MacArthur Foundation.

Table of Contents

ABBREVIATIONS

ACs	Air Conditioners
ADR	Automated Demand Response
AT&C	Aggregate Technical & Commercial
BEE	Bureau of Energy Efficiency
BLDC	Brushless Direct Current
CFLs	Compact Fluorescent Lamps
CFM	Cubic Feet per Minute
CRI	Colour Rendering Index
DC	Direct Current
DERC	Delhi Electricity Regulatory Commission
DFA	Distribution Franchisee Agreement
DISCOMs	Distribution Companies
DSM	Demand Side Management
DUF	Distribution Utilities Forum
EE	Energy Efficiency
EETs	Energy Efficient Technologies
ESCOs	Energy Service Companies
FTL	Fluorescent Tube Light
GHG	Greenhouse Gas
HP	Horse Power
HT	High Tension
ICLs	Incandescent Lamps
IE1	Standard Efficiency Class
IE2	High Efficiency Class
IE3	Premium Efficiency Class
IE4	Super Premium Efficiency
IEC	International Electro Technical Commission
kW	Kilowatt
LED	Light-Emitting Diode
LT	Low Tension
MEPS	Minimum Energy Performance Standard
MESCOM	Mangalore Electricity Supply Company Limited
MSMEs	Micro, Small, and Medium Enterprises
Mtoe	Million Tonnes of Oil Equivalent
MU	Million Units

MVL	Mercury Vapour Lamps
MW	Megawatts
NDC	Nationally Determined Contributions
O&M	Operation & Maintenance
OEMs	Original Equipment Manufacturers
PF	Power Factor
PMSM	Permanent Magnet Synchronous Motor
Power-DDL	Tata Power – Delhi Distribution Limited
RoI	Return on Investment
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SMEs	Small and Medium Enterprises
SPC	Specific Power Consumption
SPV	Special Purpose Vehicle
SVL	Sodium Vapour Lamp
TERI	The Energy and Resources Institute
ToU	Time of Use
Ujala	Unnat Jyoti by Affordable LEDs for All
VFD	Variable Frequency Drive



1. INTRODUCTION

1.1 Backdrop

Industry plays a key role in driving and sustaining economic growth; but industry is also a major consumer of fossil fuels for energy, and a principal contributor to greenhouse gas (GHG) emissions that are causing climate change. Hence, the 'decarbonizing' of industry is a primary focus of global efforts to combat climate change.

In India, the industrial sector is the largest consumer of commercial energy, and about half of it is obtained from coal. NITI Aayog estimates that the energy demand from Indian industry will triple over the next 25 years. If our nation is to sustain its economic growth and yet achieve its GHG emission reductions for sustainable growth, it is essential to find ways by which Indian industries can switch over from fossil fuels to electricity to meet their energy requirements, and also to adopt energy efficient technologies (EETs) and renewable energy (RE) options.

Roshanee: Achieving Emission Reduction Goals through Energy Efficiency

The Bureau of Energy Efficiency (BEE) has reviewed and revised the eight Missions under the National Action Plan on Climate Change (2008), to help achieve India's commitment under the Paris Agreement to reduce the emissions intensity of its GDP by 33–35% by 2030 from its 2005 level. The revised Mission on enhancing energy efficiency (EE), titled 'Roadmap of Sustainable and Holistic Approach to National Energy Efficiency' (ROSHANEE), targets the entire industrial sector, including MSMEs; it covers Demand Side Management (DSM), and has a component dedicated to EE financing. The actions under ROSHANEE are expected to mitigate over 557 million tonnes of CO_2 by 2030, with thermal energy savings of 42.71 million tonnes of oil equivalent (Mtoe) and electricity savings of 557 billion KWh at generation end.

The electricity distribution utilities (DISCOMs) can play a key role in in formulating programmes aimed at reducing GHG emissions and combating climate change, as they already have well-established commercial linkages with their industrial consumers. The challenge is to find innovative, mutually beneficial business models through which the DISCOMs can promote and support the large-scale adoption of EETs and RE options by their industry consumers, while simultaneously improving their own operational efficiency and profitability. These business models may be developed and implemented under the strategy known as **Demand Side Management.**

1.2 Demand Side Management

In simple terms, Demand Side Management (DSM) describes the planning, implementing and monitoring activities of electricity utilities that are designed to encourage consumers to modify their levels and patterns of electricity usage. DSM initiatives can be viewed under three broad categories based on their emphases and time-lines:

- Energy Efficiency—reducing overall energy consumption, as well as peak demand, over several years by encouraging consumers to adopt EETs & RE options
- Peak Load Management—reducing peak demand consistently over a season
- Demand Response—reducing peak demand for short periods of time for a few days during the year

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1 From write-up, Centre for Low Carbon Technology (TERI)

2 SN Sahay Spl Secy MoP; In SAMEEEKSHA December 2019. Also see Chart a, p.15 in https://niti.gov.in/sites/default/files/2019-07/India%E2%80%99s-Energy-and-Emissions-Outlook.pdf

DSM is a win–win option. By reducing the power demand during peak hours, it helps DISCOMs avoid the financial losses associated with short-term power purchase at high costs. By enabling consumers to adopt EETs/RE options and re-adjust the timing of their electricity use (from peak to off-peak hours), it reduces their electricity bills (Figure 1).

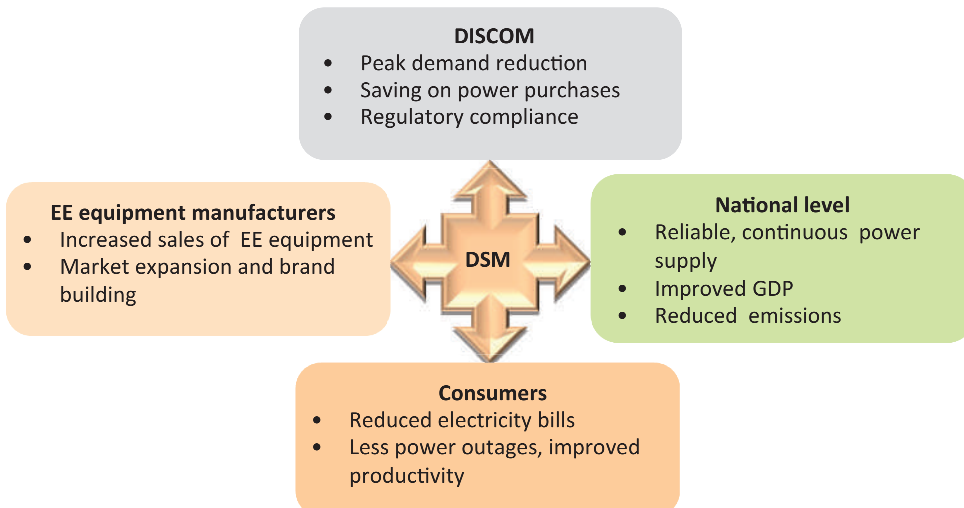


Figure 1: DSM benefits everyone

At the national level, DSM helps in balancing electricity supply with demand, and hence benefits the electricity system as a whole through ensuring more reliable and continuous power supply. As most of the electricity generated in India comes from thermal power plants, DSM in effect helps in avoiding additional GHG emissions from the power sector.[3]

1.3 The Project

In 2017, The Energy and Resources Institute (TERI) launched the Distribution Utilities Forum (DUF), an independent discussion forum to provide a platform for Indian DISCOMS to discuss issues of common interest, share experiences and come up with solutions. The same year, with support from the MacArthur Foundation, TERI undertook a load research study for the Mangalore Electricity Supply Company Limited (MESCOM), an electricity distribution company in Karnataka. Under the study a comprehensive load research was undertaken to identify potential areas for DSM interventions in different consumer categories like domestic, commercial, industrial and agriculture.

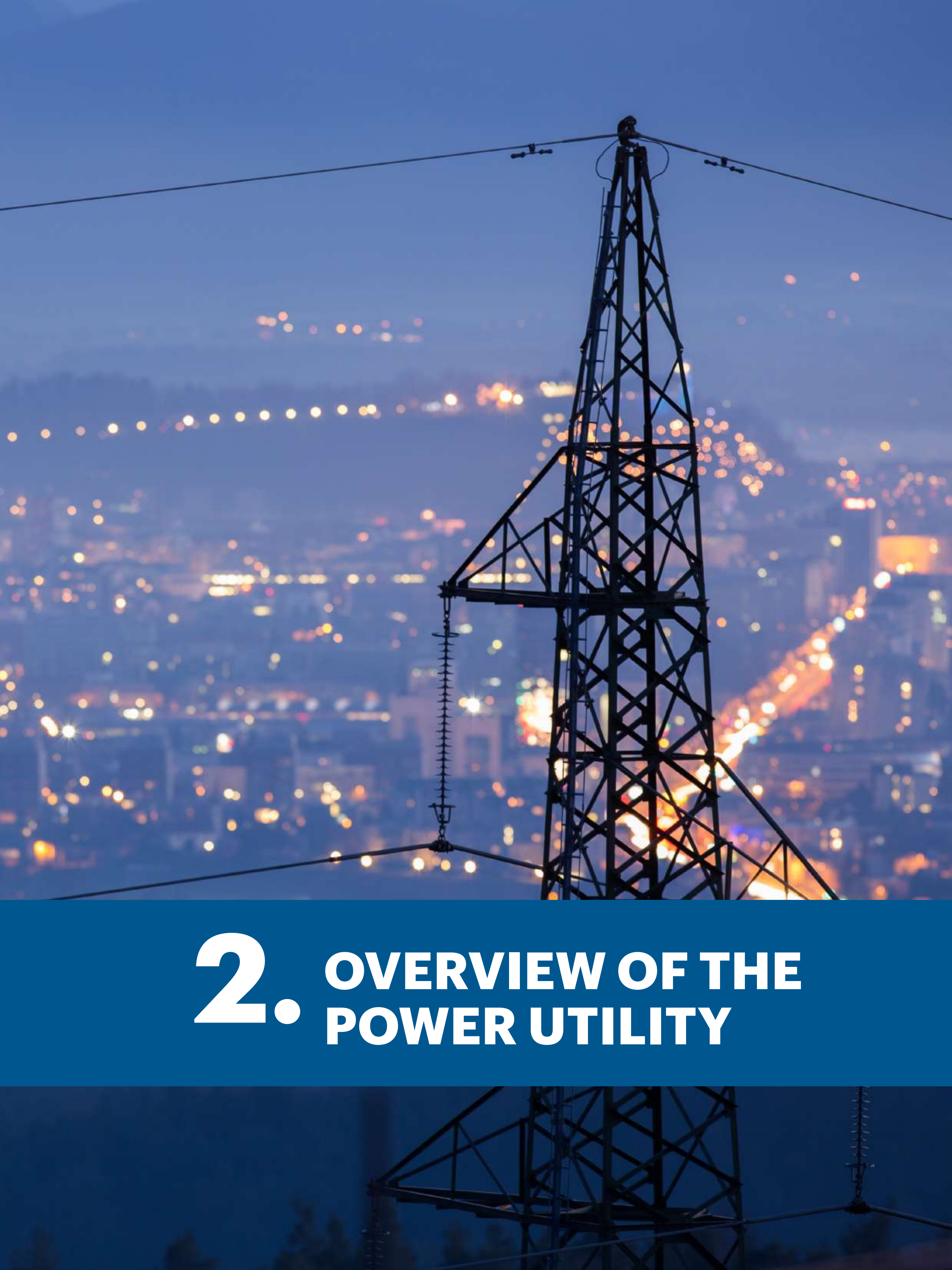
The MESCOM study underscored the fact that among industrial consumers, the need and potential for EE improvements is particularly high in the MSME sector, with the majority of MSME units continuing to depend on low-efficiency technologies and operating practices. Recognizing the enormous potential for bringing about EE improvements among MSMEs through DSM, in 2018-19, TERI, with support from MacArthur Foundation, undertook the current project to study and assess, in more detail:

[3] Coal-based power plants account for over 59% of total installed capacity in India (192.2 GW out of 326.6 GW as of March 2017). The power sector was responsible for 888.3 million tonnes of CO_2 emissions in 2016–17. Source: CEA; 'CO_2 Baseline Database for the Indian Power Sector—User Guide, Version 13.0, June 2018'. Available at http://www.cea.nic.in/reports/others/thermal/tpece/cdm_co2/user_guide_ver13.pdf

- EETs options in industrial consumer category with a focus on MSME consumers;
- Scope to 'bundle' these EETs (demand aggregation) to make them attractive business propositions for technology suppliers and utilities;
- Viable, mutually beneficial business model(s) that DISCOMs could implement under DSM programs, to promote the large-scale adoption of EETs by MSME consumers.

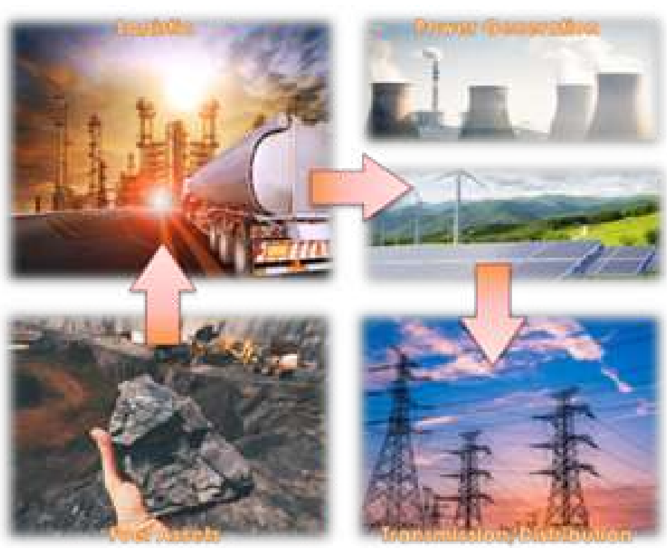
For the study, TERI forged a partnership with the largest private sector power utility, Tata Power. About 100 industrial consumers (energy-intensive MSME units) of Tata Power were identified across eight industrial sub-sectors, spread across Delhi, Ajmer, and Mumbai. Thereafter, unit-level energy assessment studies were conducted to understand the energy consumption pattern, technology in use, and operational practices. Apart from energy and equipment-level data collection, sample measurements of key parameters using sophisticated portable instruments were also conducted. During the field surveys, a team of experienced energy auditors from TERI examined the various options to save power—through the adoption of EE equipment like motors, air compressors, illumination systems, and other utilities. At the same time opportunities to save costs by demand reduction and power factor improvement were identified.

This report covers the approach and methodology adopted for the study, key findings, and recommendations for further action.



2. OVERVIEW OF THE POWER UTILITY

Tata Power is the largest private sector integrated power company in India with a significant presence in both electricity generation and distribution sectors. The company has a total installed generation capacity of 10,763 MW. It has presence in all the major segments within power sector, including fuel & logistics, generation (thermal, hydro, solar and wind), transmission, distribution, and power trading.



Tata Power is one of the largest energy players in the private sector in India. The company commissioned the country's first 4,000 MW Ultra Mega Power Project at Mundra (Gujarat) based on super-critical technology. Tata Power has successfully implemented a number of public-private partnerships in generation, transmission and distribution sectors. Some of these include 'Tata Power Delhi Distribution Limited', a partnership with Delhi Government for power distribution in North Delhi; 'Powerlinks Transmission Limited', a partnership with Power Grid Corporation of India Limited for evacuation of power from Tala hydro plant in Bhutan to Delhi; and Maithon Power Limited, a partnership with Damodar Valley Corporation for a 1,050 MW Mega Power Project in Jharkhand.

Tata Power has signed a Distribution Franchisee Agreement (DFA) with Ajmer Vidyut Vitran Nigam Limited (AVVNL) and formed a Special Purpose Vehicle (SPV), 'TP Ajmer Distribution Limited' (TPADL) to cater to the power requirements of customers in Ajmer for a period of 20 years.

At present, Tata Power has distribution licensee/ franchisee for three locations in India (see Figure 2), namely,

- Tata Power – Delhi Distribution Limited
- Tata Power – Mumbai Distribution
- Tata Power - Ajmer Distribution Limited

Tata Power serves more than 2.6 million consumers across Mumbai, Delhi, and Ajmer. The share of the industrial sector, especially energy-intensive industries, in total electricity sales / consumption in all the three utilities is significant. The industrial users currently account for about 30% of the total sales/consumption.

Key performance statistics of these three distribution licensees are given in the following sections.

Figure 2: Distribution licensee/franchisee for three locations in India

2.1 Tata Power – Delhi Distribution Limited

Tata Power Delhi Distribution Limited (Tata Power-DDL) is a private electricity distribution company incorporated under the Companies Act, 1956. It is one of the three private electricity distribution licensees in Delhi, which was established after functional unbundling and corporatization of the erstwhile Delhi Vidyut Board (DVB) in terms of the statutory Delhi Electricity Reforms Act 2000 and Delhi Electricity Reforms (Transfer Scheme) Rules, 2001.

Tata Power-DDL is engaged in the business of distribution and supply of electricity in North and North-West areas of Delhi. Figure 3 shows the utility's licensee area.

Figure 3: Licensee area of Tata Power - DDL

The entire operational area is divided into 5 circles, 12 districts and 46 zones. The operational structure of Tata Power – DDL is given in Figure 4.

Tata Power – DDL has a consumer base of 1.64 million consumers[4] (about 30% of consumers of Delhi). Figure 5 represents the consumer base of the utility, of which domestic consumers dominate the segment (82.5%) followed by commercial (13.8%) and industrial consumers (2.1%), respectively. This indicates that the utility is highly dominated by LT consumers.

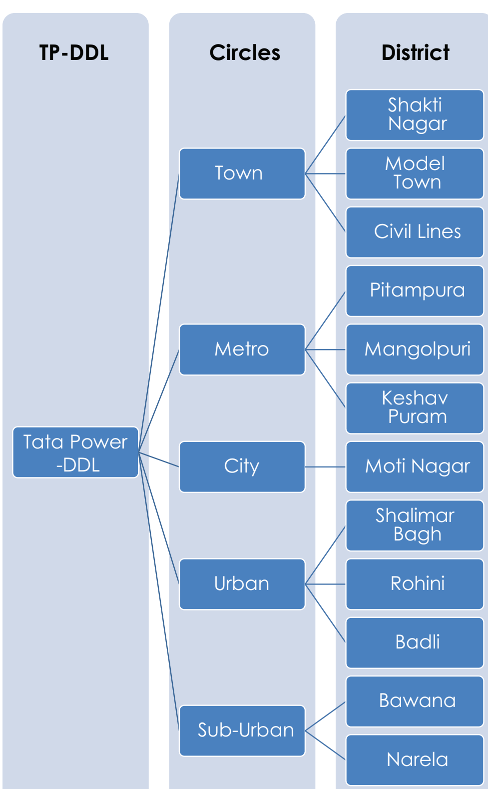


Figure 4: Operational structure

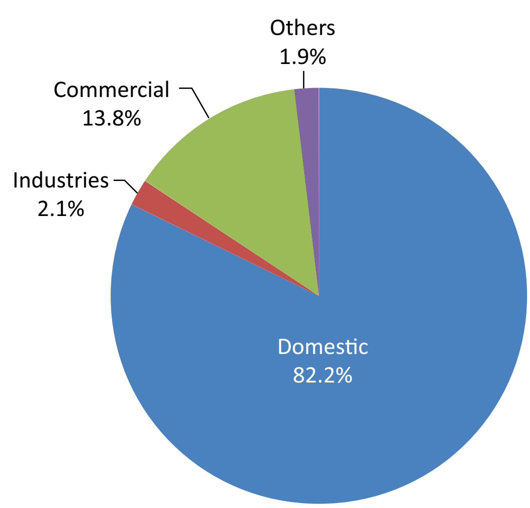


Figure 5: Consumer base of Tata Power-DDL

[4] Tata Power – DDL, ARR Volume – 1, FY 2017-18

The other key statistics of the utility are provided in Table 1.

Table 1: Key statistics of Tata Power - DDL

Particulars[5]	Values
Number of circles	05
Number of districts covered	12
Number of zones	46
Total area covered, km^2	510
Peak load demand, MW	1,967
Distribution transformers failure rate, %	0.87
Length of network (ckt. km)	12,634
System Reliability – ASAI -Availability Index, %	99.57

2.1.1 Loss Levels

The Aggregate Technical & Commercial (AT&C) loss, which is the difference between the input power units and the units for which the payment is collected, is a measure of the overall efficiency of the distribution business. Since privatization, the (AT&C) losses have shown a record decline. The AT&C loss of Tata Power – DDL is 7.92%, which is an unprecedented reduction since the inception[6] of the licensee area. The AT&C loss profile of the utility is provided in Figure 6.

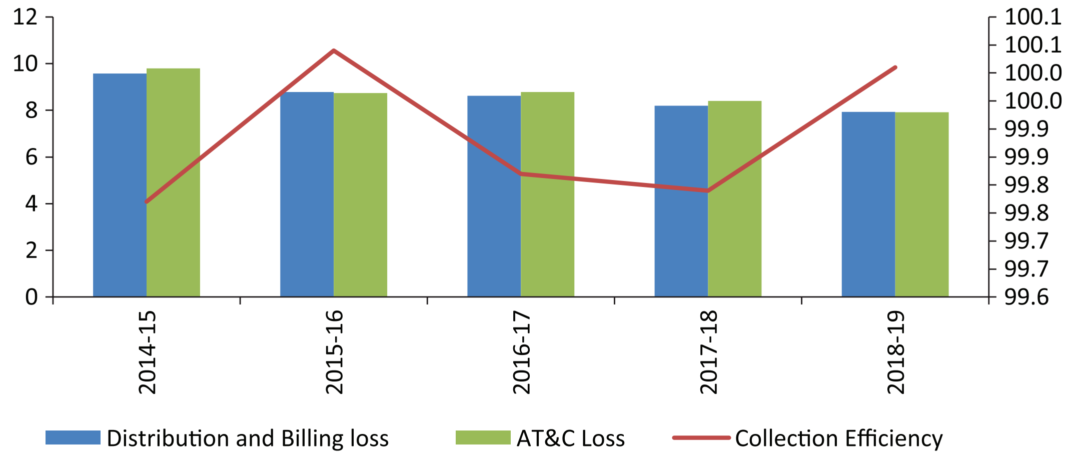


Figure 6: Losses and collection efficiency of Tata Power – DDL (sp collection)

In addition to this, the two reliability indices of the utility, viz. System Average Interruption Frequency Index (SAIFI), which is the average number of sustained interruptions per consumer during the year, and System Average Interruption Duration Index (SAIDI), which is the average duration of interruptions per consumers during the year, are among the lowest among similar distribution companies. The month-wise SAIFI for FY 2017–18 for the utility is shown in Figure 7.

[5] As on March 2019

[6] AT&C loss was 53% in the year 2002

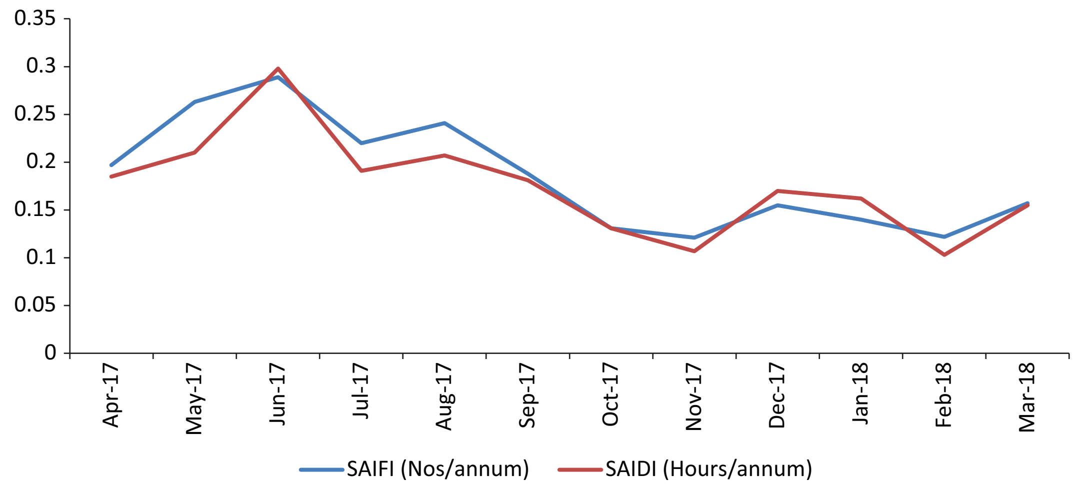


Figure 7: System average interruption frequency index (SAIFI) of Tata Power - DDL

2.1.2 Electricity Consumption & Sales

During FY 2017–18, Tata Power-DDL procured 9401.41 million units (MU) at a cost of ₹5,208 crore. The average cost of power purchases was about ₹5.54 per kWh. The total sales of the utility during the year were 8630.87 MU. Figure 8 shows the category-wise sales during FY 2017–18. The consumption mix of the utility is dominated by domestic consumers (46%), followed by industrial consumers (28%).

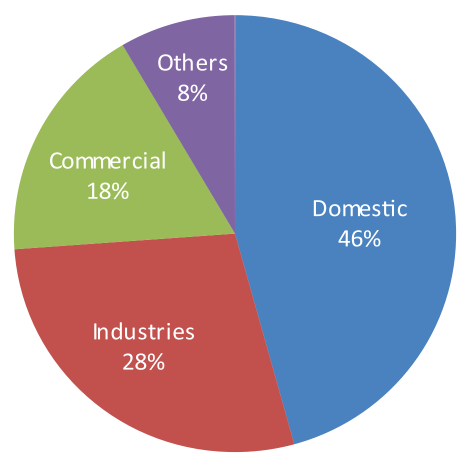


Figure 8: Category-wise electricity consumption, FY 2017–18

2.2 Tata Power – Mumbai Distribution Limited

Tata Power Mumbai Distribution Limited [Tata Power-Mumbai] is a private electricity distribution company engaged in the supply of electricity to the entire city of Mumbai and its suburbs. Broadly the licensed area can be divided into the following licensee areas:

- Colaba to Mahim falling under the Mumbai City Revenue District;
- Bandra to Dahisar falling under Western suburban parts of Mumbai Suburban Revenue District;
- Chunabhatti to Vikhroli and Mankhurd in Eastern suburban parts of Mumbai Suburban Revenue District; and
- Mira Bhayander Municipal Corporation.

[7] Tata Power Delhi Distribution Limited; True Up for 2017-18; DERC

Figure 9 shows the utility's licensee areas.

The distribution licence has been granted for a period of 25 years effective from 16th August, 2014 and shall remain in force till 15th August, 2039.

In FY 2018–19, Tata Power–Mumbai had a consumer base of 0.70 million consumers.[8] Figure 10 depicts the consumer base of the utility. Domestic consumers dominate the segment (94.0%) followed by commercial (5.3%) and Industrial consumers (0.6%) respectively. The utility is highly dominated by LT consumers.

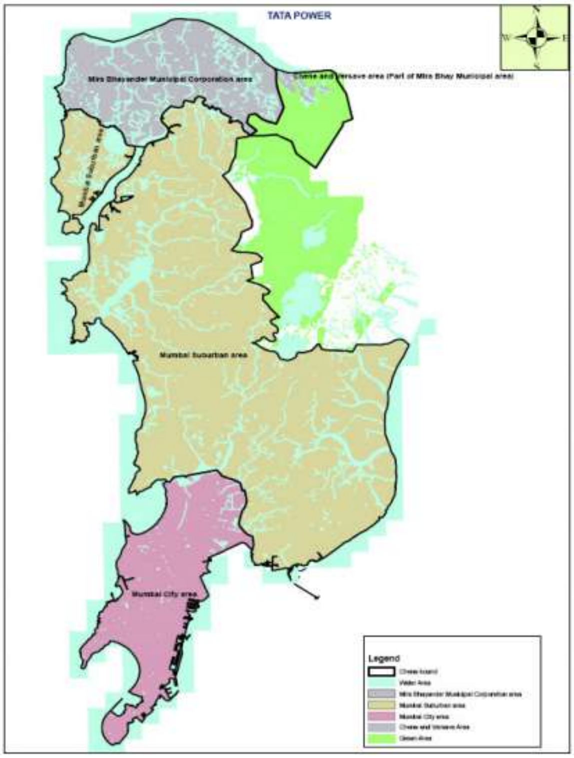


Figure 9: Licensee area of Tata Power –Mumbai

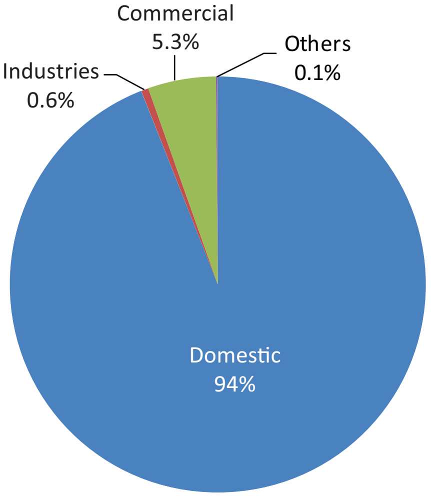


Figure 10: Consumer base of Tata Power -Mumbai

[8] Tata Power – DDL, ARR Volume – 1, FY 2017-18

The other key statistics of the utility are provided in Table 2.

Table 2: Key statistics of Tata Power-Mumbai

Particulars[9]	Values
Number of circles	05
Number of districts covered	12
Number of zones	46
Total area covered, km^2	510
Peak load demand, MW	909
Distribution Transformers failure rate, %	0.87
Length of Network (ckt. km)	1200
System Reliability – ASAI -Availability Index, %	99.48

2.2.1 Loss Levels

The AT&C loss of Tata Power–Mumbai is below 2% and losses have shown a steady during few years. The actual AT&C losses of the utility during the FY 2018-19 works out to be 0.78%. The transmission and AT&C loss profile of the utility is provided in figure 11.

Figure 11: Transmission and distribution loss of Tata Power –Mumbai

The reliability indices, SAIFI and SAIDI of the utility are at least level with those among similar distribution companies. The values of SAIFI (frequency of interruption) and SAIDI (duration of interruption) for FY 2018–19 were 0.51 and 12.50, respectively. The daily average interruption frequency index for a sample period during FY 2018–19 is given in Figure 12.

[9] As on March 2018

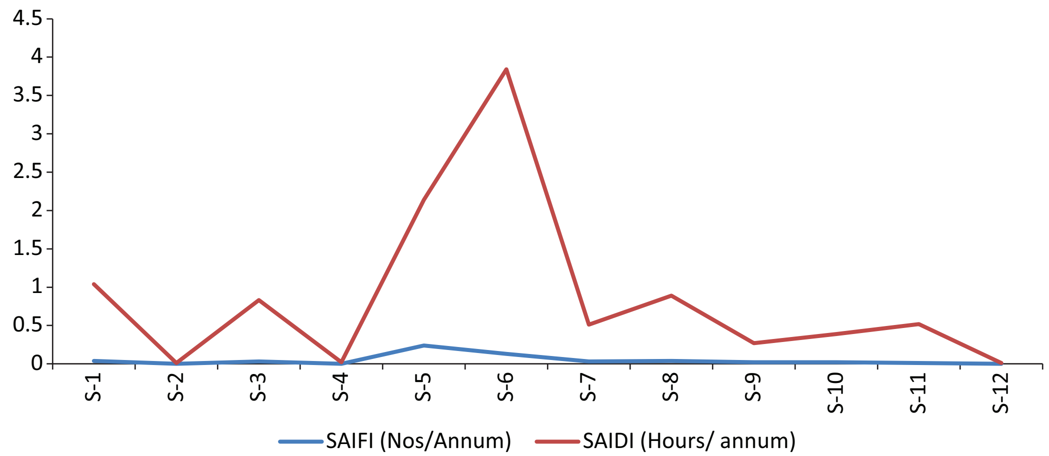


Figure 12: System average interruption frequency index of Tata Power-Mumbai

2.2.2 Electricity Consumption and Sales

During FY 2017–18, Tata Power-Mumbai procured 4,691 MU of electricity at a cost of ₹2,442.92 crores[10]. The average power purchase price was ₹5.21 per kWh. The total sales of the utility for FY 2018–19 were 4,525 MU. Figure 13 shows category- wise sales of Tata Power- Mumbai during FY 2018–19. The consumption mix in the utility is dominated by domestic consumers (41%) followed by industrial consumers (26%).

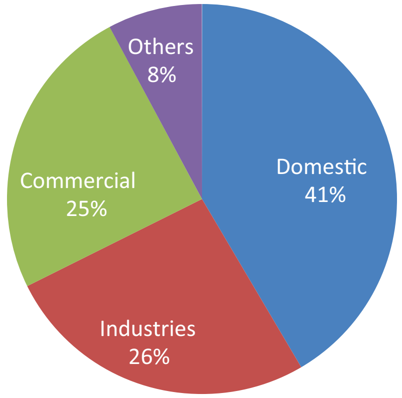


Figure 13: Category-wise electricity consumption of Tata Power, Mumbai

2.3 Tata Power – Ajmer Distribution Limited

Tata Power Ajmer Distribution Limited (Tata Power-ADL), an SPV, has signed a Distribution Franchisee Agreement (DFA) with Ajmer Vidyut Vitran Nigam Limited (AVVNL) to cater to the power requirements of customers in Ajmer for a period of 20 years starting from 2017.

[10] Tata Power Delhi Distribution Limited; True Up for 2017-18; DERC

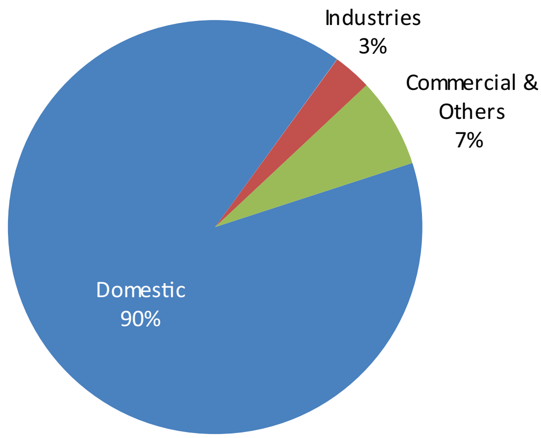


Figure 14: Consumer base of Power-ADL

Tata Power-ADL had a consumer base of 0.14 million consumers[11] for FY 2018–19. Figure 14 depicts the consumer base of the utility; as can be seen, domestic consumers dominate (90%), followed by commercial & others (7%) and industrial consumers (3%), respectively. This clearly indicates that the utility is highly dominated by LT consumers.

The other key statistics of the utility are provided in Table 3.

Table 3: Key statistics of Tata Power-ADL

Particulars[12]	Values
Number of circles	1
Number of divisions	2
Number of sub-divisions	7
Number of distribution transformers,	2,800
Length of Network (ckt. km) - 33 kV	260
Length of Network (ckt. km) - 11 kV	774
Length of Network (ckt. km) - LT	1,600

2.3.1 Loss Levels

The AT&C loss of Tata Power-ADL is 11.2%. The AT&C losses have shown a record decline. The AT&C loss profile of the utility is shown in Figure 15.

[11] Tata Power – Ajmer Distribution Limited, FY 2017-18

[12] As on March 2019

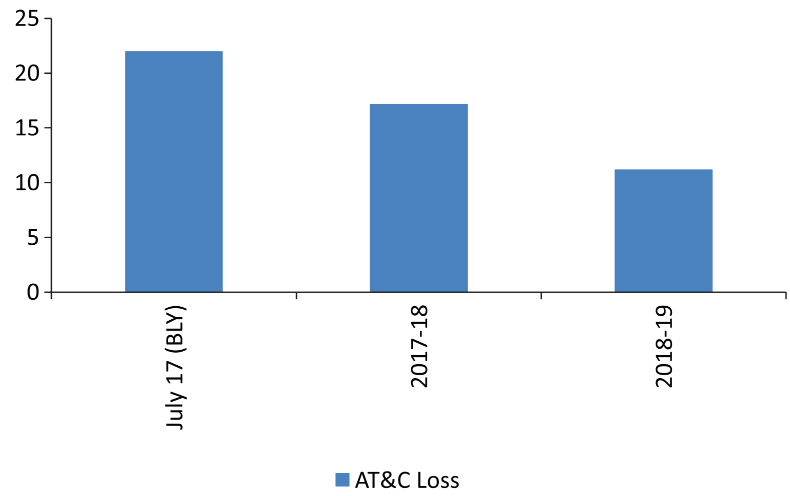


Figure 15: Transmission and distribution loss of Tata Power–ADL

2.3.2 Electricity Consumption & Sales

Tata Power-ADL has procured 523 MU during 2018–19 and total sales of the utility for the year were 465 MU. The consumer category-wise sales of Tata Power-ADL during FY 2018–19 were not available.

2.4 Energy Efficiency and DSM Initiatives of Utilities

Some of the benefits of implementing DSM activities and programs are the following:

- Lower overall cost of electricity to the consumers by economical and efficient use of resources.
- Complement supply side strategies to help in meeting electric service demands by assisting utilities (generation, transmission and distribution) to avoid or delay costly additions.
- Reduce the difference between power demand during peak periods and off- peak period

Tata Power has been at the forefront of propagating energy conservation, efficiency and DSM initiatives in the country. The DSM initiatives of Tata Power are aimed at educating consumers about energy and its proper usage, and the necessary steps that consumers should take to reduce their demand for electricity.

Delhi and Maharashtra initiated DSM activities in 2007–08. The Maharashtra Electricity Regulatory Commission (Demand Side Management Implementation Framework) Regulations were issued in 2010, while the Delhi Electricity Regulatory Commission (DERC) notified the state level DSM regulations in the year 2014.

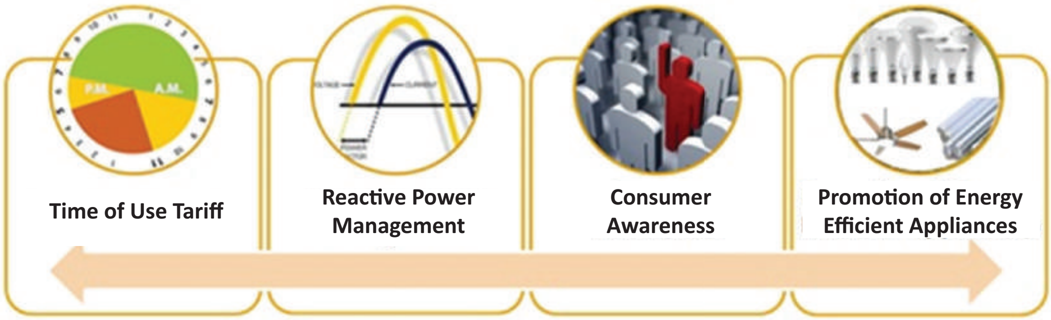


Figure 16: Key DSM initiatives of Tata Power DDL

Apart from the tariff level interventions (i.e. time of use (ToU) tariff and reactive power management), Tata Power has initiated several programs under DSM In response to the increased power demand in Mumbai and the rest of the country. The initiatives were planned with the objective of helping consumers save energy without compromising on their comfort. These DSM programs have been based on extensive load research, understanding the consumer load curve, time of use, ownership of electrical goods, load profile and affordability of energy-efficient products.

Program

The DSM initiatives which have the objective of reducing peak load and flattening the load curve are outlined below.

- **Star rated air-conditioner program:** The share of the domestic category in the total sanctioned load is significant. Most of the domestic consumers use air conditioners (ACs), either non-star or less than 3 stars. Night-time system peak load is primarily attributed to the domestic AC load. Thus, the utility has been promoting the replacement of non-star rated ACs with BEE 5 Star rated / Inverter Technology ACs. Under the scheme, old ACs are disposed off in an environment-friendly manner to prevent their re-entry through the grey market. Around 17,500 non-star ACs have been replaced in under this program.
- **Discount scheme for energy efficient appliances:** Tata Power was the first utility to launch a DSM program for discounted LED lighting, star-labelled and BLDC ceiling fans directly in partnership with original equipment manufacturers (OEMs) like Crompton Greaves, Osram, and Atomberg Technologies. Under this scheme, a range of LED lighting products (i.e. LED bulbs, tube lights, panels, down lighters, etc.) and ceiling fans were offered to the customers at discounted prices through various district customer care centres. This program was open to all consumer categories. Since the energy efficient appliances were available at a discount of 20–40% on market price, the program was a huge success.

- **Energy Efficient LED Lighting Program:** Under the domestic efficiency lighting program (DELP) and Unnat Jyoti by Affordable LEDs for All (UJALA) program of Energy Efficiency Services Limited (EESL) efficient LED lights (LED bulbs of 7/9W and LED tube lights of 18/20 W) and BEE 5 star rated ceiling fans are being offered at discounted rates through distribution counters of Tata Power. This program is also open to all consumer categories of Tata Power.

- **Automated Demand Response (ADR):** To manage the short-term demand of the utility, automated demand response program was implemented by Tata Power-DDL among industrial and commercial consumers. This initiative allows consumers to make informed decisions and optimize their electricity usage based on time-based rates, and avail of incentives in ADR events. The consumer can avail of a tariff rebate of 40% in case of ADR events within two hours notification (immediate intimation), and 20% in case of ADR event with more than two hours notification (advance intimation)..
- **Consumer awareness:** Tata Power-DDL has initiated a number of awareness programs to sensitize consumers on efficient use of electrical appliances in their premises. Some of the programs are summarized below.

  » CLUB ENERJI (Climate change impact: Sensitising the future generations): Tata Power started a program to sensitize school children on energy conservation techniques. A bilingual energy conservation booklet containing tips on energy and resource conservation, climate change and electrical safety is distributed to member students every year. A yearly event - Urja Mela - is also organized to recognize children's contribution towards innovation in energy conservation.

The cumulative energy saving realized through the implementation of DSM initiatives in various consumer categories by Tata Power – Delhi Distribution Limited resulted in saving 84.72 million units per year.

» Energy Saving Calculators: These calculators enable consumers to estimate the energy and cost savings by the adoption of energy efficient appliances and products.

» Tips on Energy Usage: An information portal provide general tips and solutions to conserve and optimize the use of electricity.

» Energy Audit of Key Consumers: Making consumer aware on electricity and operating cost savings potential by adoption of energy efficient products.

Apart from the above mentioned initiatives, Tata Power is also organizing regular meetings with Resident Welfare Associations (RWAs) and annual Consumer Meet " Milaap" to understand the need of consumers.

3. APPROACH & METHODOLOGY

There are a number of important prerequisites for formulating EE-based DSM action plans for the utilities. These include a clear understanding of the demand variation (both diurnal and seasonal), the contribution of different consumers to the demand, prevailing technology status and so on. Accordingly, a comprehensive study of the utility profile is required for identifying the major consumer categories. For industrial consumers, the share of the electricity consumption by sub-sector is required. This will involve an analysis of the electricity sales profile for major sub-sectors. Thereafter, detailed assessment studies of representative units in each sub-sector are required to identify the key energy consuming technologies and the scope to save energy by replacing the existing technologies with new efficient technologies. Once the demand for a new efficient technology is identified, innovative financial models could be devised by the utility to accelerate their adoption. This approach is schematically shown in Figure 17.

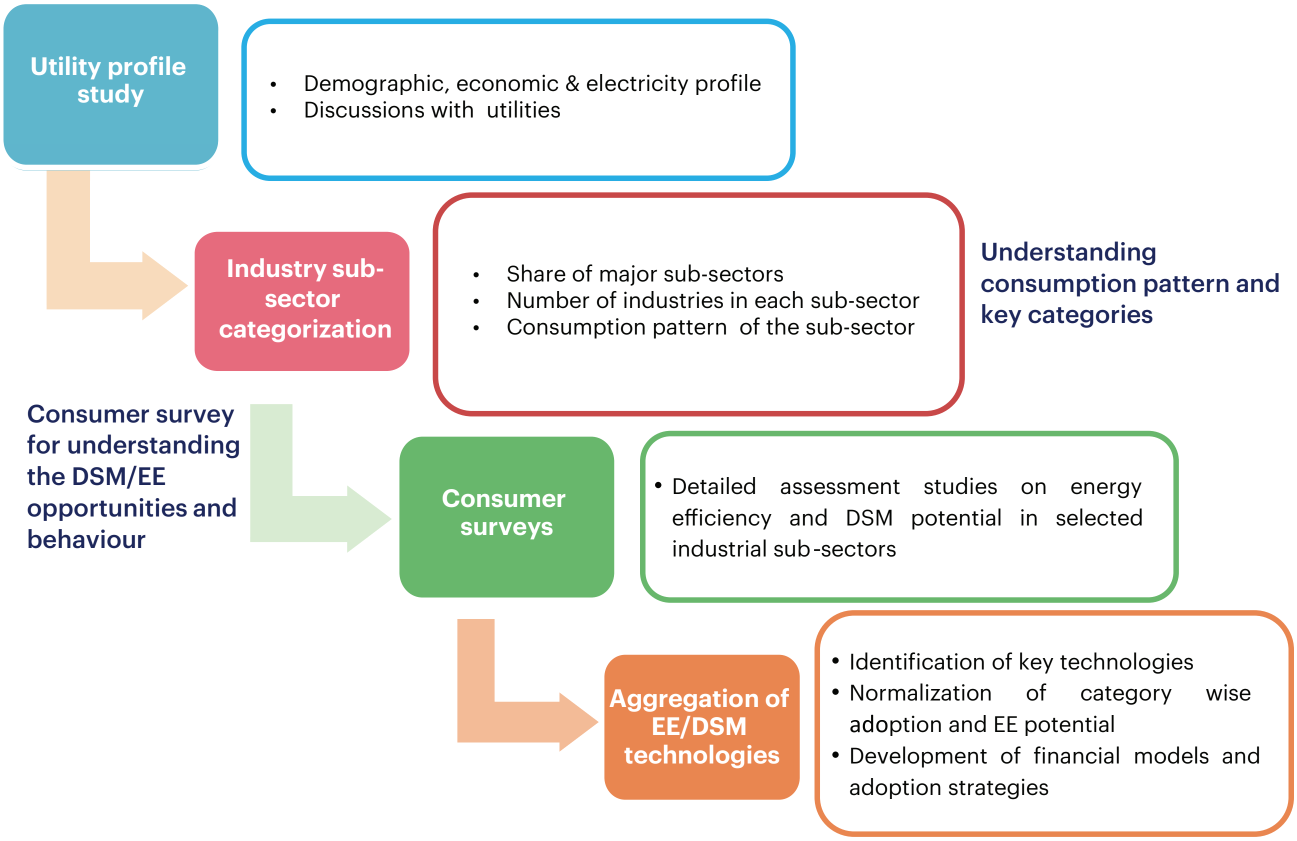


Figure 17: Schematic of key steps and activities under the project

The methodology adopted for the DSM study is detailed below.

3.1 Utility Profile Study

A study was undertaken of three distribution areas of Tata Power, spread across Delhi, Ajmer, and Mumbai. A profile of the industrial consumers in each of the distribution areas and their electricity consumption was prepared in order to understand the demand pattern of electricity. The DSM initiatives which have been undertaken by the utility and their impacts were also studied in order to gauge the interventions which might work in the future.

3.2 Industry Sub-sector Categorization

In order to understand the pattern of energy consumption in the industrial sector, a categorization of major end-use industrial sectors was undertaken. This provided an insight into energy usage pattern in different industries types so that major industrial sub-sectors could be targeted for detailed assessment.

Industry sub-sectors for conducting detailed energy assessment studies were then selected after an analysis of the percentage share of energy-intensive industrial sub-sectors.

3.3 Consumer Survey

To understand the energy consumption pattern of the identified industrial sub-sector, a sample energy assessment of industries was conducted. A stratified random sampling technique has been used for selecting the samples based on their share in industrial energy consumption, the number of units in each sub-sector, and the willingness of the industrial unit to participate in the survey. Apart from total energy consumption, the energy intensity of the sector and opportunities to adopt replicable energy conservation measures were also taken into consideration.

The industries identified for the sample survey were further divided into HT and LT consumer categories.

A structured data questionnaire was prepared to collect energy-related information from the shortlisted consumers and operating parameters of the energy-consuming equipment installed. Sample measurements of key energy-consuming equipment and processes were also conducted during the field assessment studies.

3.4 Aggregation of EE/DSM

The survey helped in identifying the major EE/DSM opportunities and the energy-saving potential of each technology in the industrial consumer category. To aggregate the total demand of the energy saving technologies identified, statistical techniques for extrapolation were used.

The computations of the aggregate demand will enable the utility to gauge its impact on the consumption pattern of the industrial sector.

Based on the type of technologies identified, ESCO-based business models for promotion/adoption of the new technologies were prepared. The models included documenting roles and responsibilities of all key stakeholders such as utilities, equipment vendors, ESCOs, industry associations, state designated agencies, banks/financial institutions, energy audit agencies and so on.

3.5 Stakeholder Consultation

To understand the perspective of different stakeholders concerning energy efficiency and DSM measures in industries, extensive interactions were carried out in all the three distribution areas with different stakeholders including utility officials, industry representatives, consumer associations, and technology providers. This process helped in developing an understanding of ground-level realities, market characteristics, barriers, and possible solutions to address the barriers.

Based on the study, potential areas of interventions for different EE technologies, including rationale and appropriate business models for implementation, were identified.

4. DEMAND SIDE LOAD RESEARCH

Assessment studies were conducted by TERI among SMEs in the licensee areas of Tata Power in Delhi, Mumbai, and Ajmer to identify the scope for adoption of energy-efficient technologies for demand-side interventions.

A sample of 100 MSME units across various industrial sub-sectors was selected for the survey. The distribution of the units across the three utilities is shown in Figure 18.

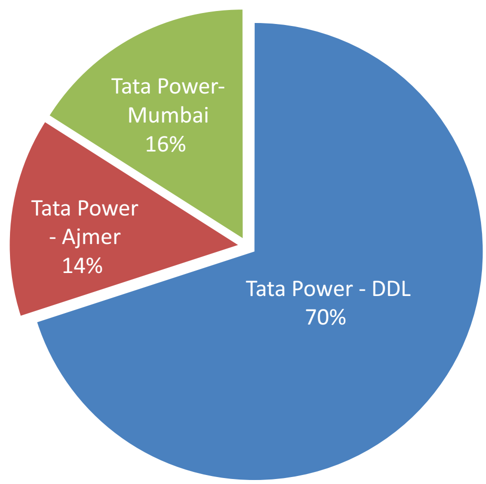


Figure 18: Distribution of surveyed MSME units across the utilities

4.1 Sample Selection

The category-wise energy sale was discussed with the utilities to identify key energy-intensive industrial sub-sectors. Major energy-intensive industrial sub-sectors in the selected three utilities of Tata Power are depicted in Table 4.

Table 4: Major energy-intensive industrial sub-sectors in the three utilities

Utility	Major industrial subsector
Tata Power DDL	Engineering Food Processing Cold Storage Steel/Foundry Textile Plastics Dal and Flour Mill
Tata Power Mumbai	Engineering Food Processing Textile
Tata Power ADL	Engineering Food Processing Cold Storage Steel/Foundry Plastics

Sample units for assessment were selected in consultation with Tata Power. Some selection criteria which were considered while selecting the units included the following: energy sales and intensity, number of units in the sub-sector, the willingness of the industrial unit, potential for replication of energy conservation measures, mix of HT and LT categories, and so on.

The break-up of units selected from each sub-sector in the three utilities is given in Figure 19.

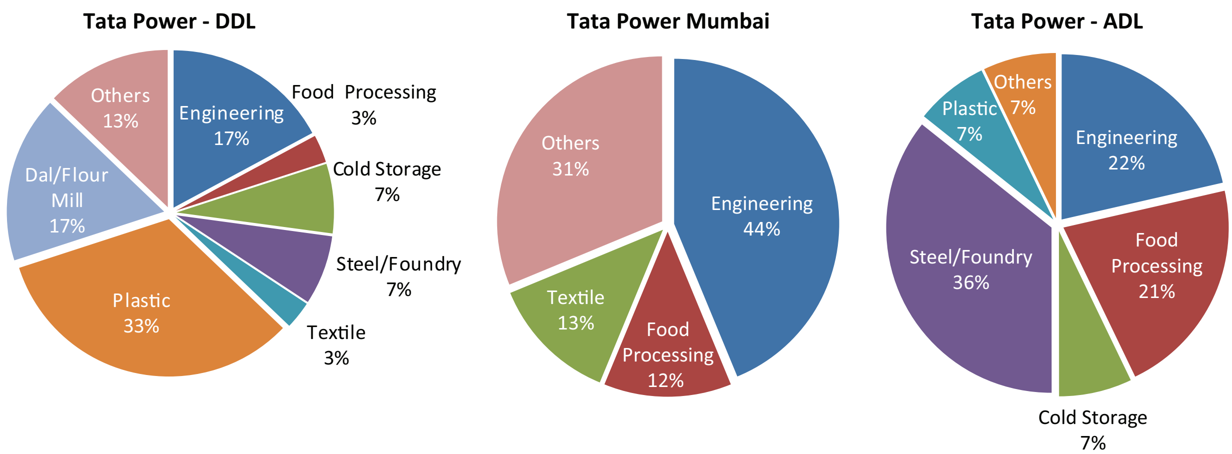


Figure 19: Share of assessment studies by industrial sub-sector

An overview of the major energy-intensive industrial sub-sectors and the major DSM opportunities among them are given in Annex 1 to 7.

4.2 Assessment Studies

The selection of the SMEs was followed by unit-level energy assessment studies involving data collection, sample measurements of key parameters using sophisticated portable instruments, and analysis. During the field surveys (Figure 20), energy auditors from TERI looked at various options to save power by adopting energy efficient equipment like motors, pumps, fans, etc., apart from power quality issues.

The assessment studies were useful in identifying the DSM opportunities and energy saving potential among energy-intensive equipment installed in the SMEs.

Figure 20: Energy assessment studies in Tata Power

4.3 Energy-intensive Equipment

The studies found the following common energy-intensive appliances in use in the identified industrial sub-sectors:

- Electric motors
- Air compressors
- Lighting
- Space cooling/ air circulation fan

The operational pattern, density, and ownership of these appliances in the industrial consumer category are described in the following sections:

4.3.1 Electric Motors

4.3.1.1 Introduction

Electric motors help convert electrical energy into rotary motion. Industrial motors are primarily of two types – induction motors and direct current (DC)/synchronous motors. Motors used in the industry could range in capacity from fractional horsepower (HP) motors (below 1 HP) to motors of 500 HP (375 kW) or sometimes even larger capacity.

Electric motors accounted for the largest share of electrical load, electricity consumption, and overall numbers among the majority of SMEs covered under the study. The industries use induction motors in both utility and process applications. Utility applications include the use of motors in air compressors, fans & blowers, pumps, etc. Also, motors are used in several process applications such as various machines used for milling, grinding, mixing, polishing, cutting, etc. The usage of these motors varies between 2–3 hours to continuous operation (24 hours), depending on the application.[13]

4.3.1.2 Density

The appliance density is an indicator of the penetration level of the appliance. In other words, it is the number of similar appliances installed per enterprise. While estimating the appliance density,[14] the equipment was further categorized based on rated/design capacities, technology type (i.e., efficiency class, etc.) Findings from the assessment are elaborated in the following sections:

A total of more than 1100 motors of different capacities were studied under the project. While most of these motors ranged between 0.75–75 kW, a few motors were found of higher capacities, ranging between 90–150 kW.

The average density of electric motors of various capacities found to be commonly used among industries is shown in Figure 21.

[13] Stand-alone motors were considered in the study. The motors associated as integral parts of equipment are not considered for analysis

[14] Appliance density is the ratio of number of equipment of selected technology to number of respondents (units)

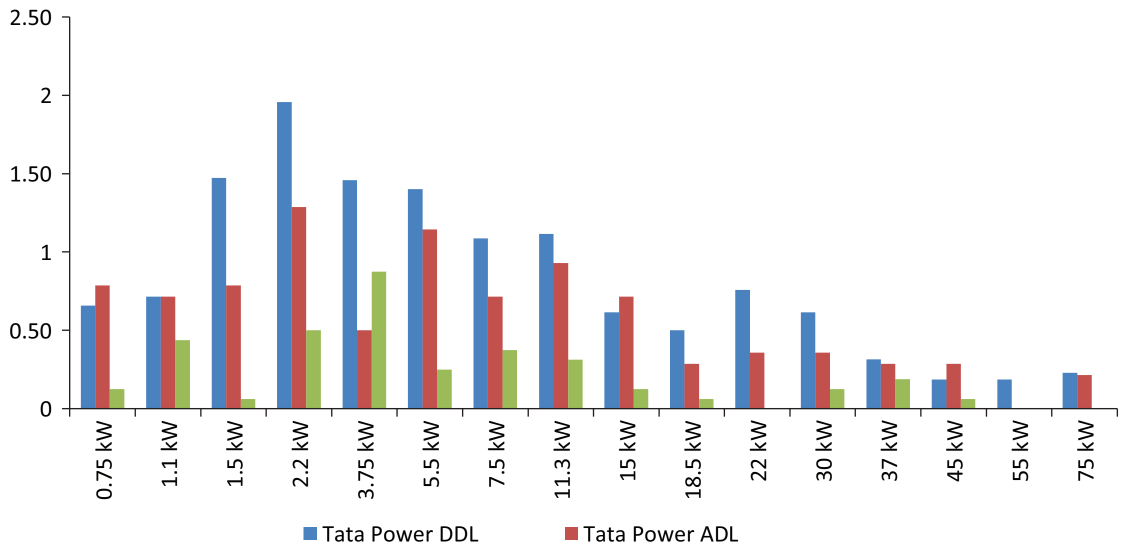


Figure 21: Density of electric motors in industrial consumer categories

The total connected load of electric motors was found to be about 11.9 MW which constituted about 49% of the total industrial load. Electric motors can be further sub-classified according to their capacity into the following three categories:

- Small capacity motors (0.75–7.5 kW)
- Medium capacity motors (11–30 kW)
- High capacity motors (37–75 kW)

The capacity-wise shares of motors installed in the surveyed units in the three utilities are shown in figure 22. As can be seen from the figure, the population of the motors is dominated by the small capacity motors (63–75%) followed by medium capacity motors (15–27%).

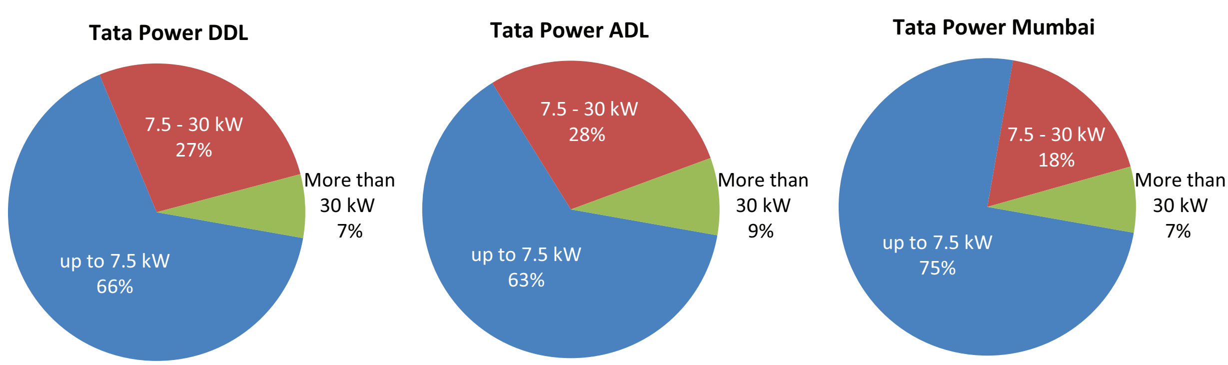


Figure 22: Capacity-wise shares of installed motors in surveyed units

The other observations from the analysis of motor density among the three utilities were as follows:

- Tata Power DDL: The overall connected load of electric motors was about 10 MW in the 70 SMEs surveyed. Electric motors constituted about 62% of the total contract demand of these units. While the majority of the motors were in the small and medium capacity range (0.75–30 kW), the highest density was observed in the range of 1.5 kW to 11.3 kW capacity.

- Tata Power – Mumbai: The overall connected load of stand-alone electric motors was found to be about 0.5 MW in the 16 units surveyed. The motors constituted about 15% of the total contract demand of the surveyed units in Mumbai. This was because most of the motors in use among industries there were of integrated type. While the majority of the motors ranged in capacity between 0.75–45 kW, the highest density was in the 1.1 kW–3.75 kW range.
- Tata Power ADL: The overall connected load of motors was found to be about 1.5 MW in the 14 units surveyed. The motors constituted about 29% of the total contract demand of the surveyed units in Ajmer. While the majority of the electric motors ranged in capacity between 0.75–75 kW, the highest density was in the 0.75–15 kW range.

The connected load of the motors in the three utilities is given in Figure 23. As can be seen from the figure, medium capacity motors (i.e. 11–30 kW) accounted for the major chunk (35–46%) of the overall load of the electric motors among all industrial consumers. This was followed by high capacity motors (37–75 kW) which accounted for about 33–38% of the connected load.

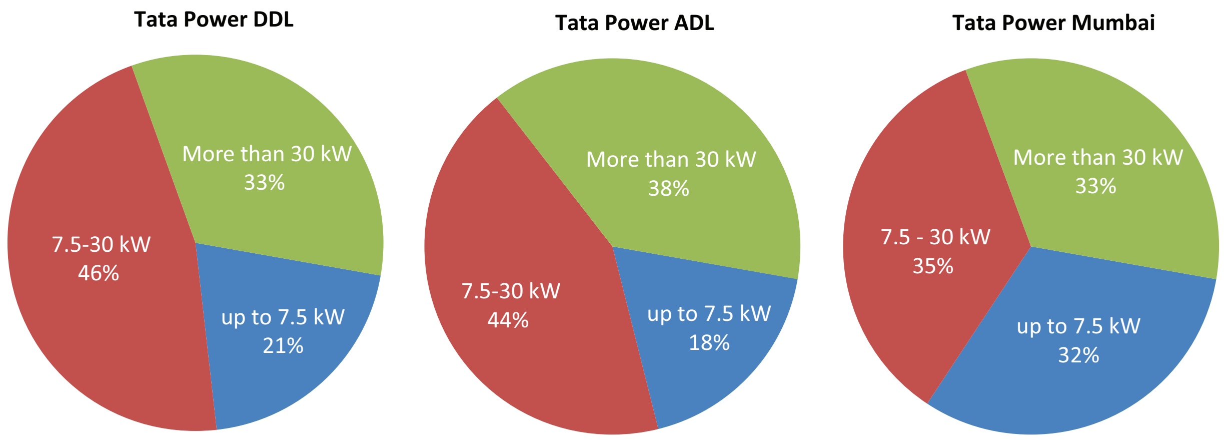


Figure 23: Capacity-wise share of motors in connected load

4.3.1.3 Performance assessment

Not all the energy input to a motor is converted to usable mechanical energy. Some of the energy is lost as waste heat during the conversion process. Such losses occur at each step in the electric motor, and hence the energy losses accumulate along the way and can result in significant overall waste. The process of converting electrical energy into mechanical energy delivered at the motor shaft incurs losses including (i) copper losses (I2R losses), (ii) core losses, (ii) windage and friction losses, and (iv) stray load losses.

The relative proportions of the individual energy loss[15] components, and their variations with the motor size, are shown in Figure 24.

[15] Reference: 50-Hz, four pole squirrel cage induction motors (Source: de Almeida, Anibal T. and others (2014) EuP Lot 30: Electric Motors and Drives. ISR University of Coimbra and Atkins)

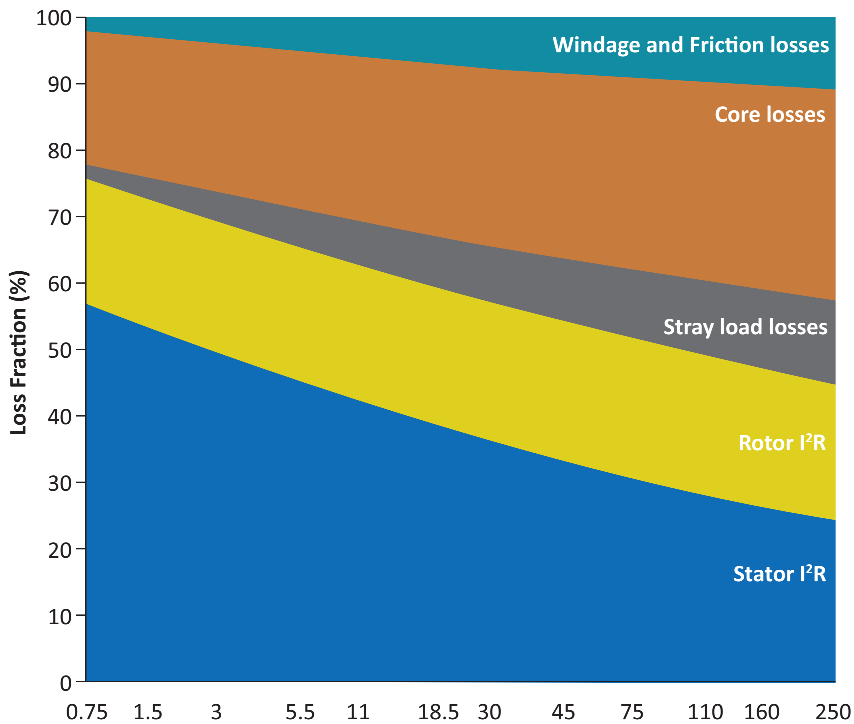


Figure 24: Typical fraction of losses in electric motors

The percentage of the input electrical energy converted into usable mechanical energy is defined as the energy efficiency of a motor.

During the study, the performance assessment of the electrical motors was carried out to identify the potential for energy savings. The study included electric motors associated with utility and manufacturing process equipment. The assessment broadly focused on the following aspects:

- Efficiency class of electric motors
- Loading pattern (by measuring the actual power consumption of the individual motors)
- Operational practices

Efficiency class of motors

The International Electrotechnical Commission (IEC) is an international standards organization that prepares and publishes standards for electrical equipment.

IEC Standard 60034-30-1 categorizes electric motors based on their energy efficiency, from IE1 (lowest efficiency) through IE2 (high efficiency) and

Super Premium Efficiency (IE4) class electric motors

To boost the competitiveness of manufacturing sector, it is worth to invest in IE4 efficiency class electric motors. The IE4 motors offer highest efficiency in "Induction Motor Technology"

- IE4 motors have up to 22% lower losses than IE3 motors.
- In comparison to IE1, IE4 line motors provides with an efficiency that is up to 14% higher – and up to 3% higher than IE3
- High degree of roughness for use in aggressive ambient conditions
- Fit for the future through optional convertor operation
- Simplified retrofits as IE2, IE3 and IE4 motors all have the same shaft height (frame)

IE3 (premium efficiency) to IE4 (highest or super premium efficiency). A large number of motors around India do not even meet IE1. The country declared IS 12615 as mandatory certification from January 1, 2018, under which minimum energy performance standard (MEPS) is IE2; or because it is an old motor (before regulation). Applicable minimum energy performance standards for electric motors worldwide are given in Annex – 8.

Of all the motors under the study, about 97% were found to be of standard efficiency class (IE1) and just about 3% were found to be of high efficiency class (IE2). The electric motors of efficiency class IE1 and IE2 deliver significantly lower performance and efficiency than the premium efficiency (IE3) and super premium efficiency (IE4) class motors (see box). This low performance and low efficiency result in higher power consumption by individual motors. Therefore, it is a matter of concern to find such a significant number of motors in operation that fall under the low efficiency category. This also underlines considerable wastage of power among these the motors.

Loading pattern of motors

Motors usually perform at lower efficiency when they run on part load, that is, below their rated output. They are usually most efficient when operating in the range of 70–80% of the rated capacity. In regular operations, most of the motors under the study were found to be under-loaded against their actual capacities. For IE1 and IE2 motors, the efficiency drops further under part-load conditions and therefore, results in higher power consumption.

Operational practices

Burning out of motors due to overload and poor operational practices was found to be quite common among most of the industries. Further, most of these motors are either rewound by local service providers or repaired in-house by the industries themselves, rather than by approaching the concerned manufacturers. This often leads to misalignment of the rotor and the stator and improper winding, and a drop in the efficiency of the motor by about 2–3% with each rewinding. During the study, it was found that about 40% of the motors in use have been rewound multiple times.

4.3.1.4 Energy efficiency measures

As per the standard IS12615: 2018 adopted by the Bureau of Indian Standards (or IEC: 60034-30) the efficiency of electrical motors is categorized under the following four classes in the order of ascending efficiency –

- IE1 – standard efficiency
- IE2 – high efficiency
- IE3 – premium efficiency
- IE4 – super premium efficiency

Higher efficiency motors are usually manufactured from materials that incur lower energy losses as compared to standard motors. More care is taken with the design and geometry of the motor construction. These motors have been improved in the following four areas:

- Longer core lengths of low loss steel laminations to reduce flux densities and iron losses.
- Maximum utilization of the slots and generous conductor sizes in the stator and rotor to reduce copper losses.
- Careful selection of slot numbers and tooth/ slot geometry to reduce stray losses.
- Less heat is generated due to a more efficient design. Thus the cooling fan size is smaller, leading to lower windage losses and lesser wastage of power.

Although IE4 is the highest class of efficiency of electrical motors, the market intervention and availability of this class of motors is limited. This makes the IE3 class of motors the most viable option from the energy efficiency viewpoint. Figure 25 shows a comparison between the IE1, IE2, and IE3 class motors.

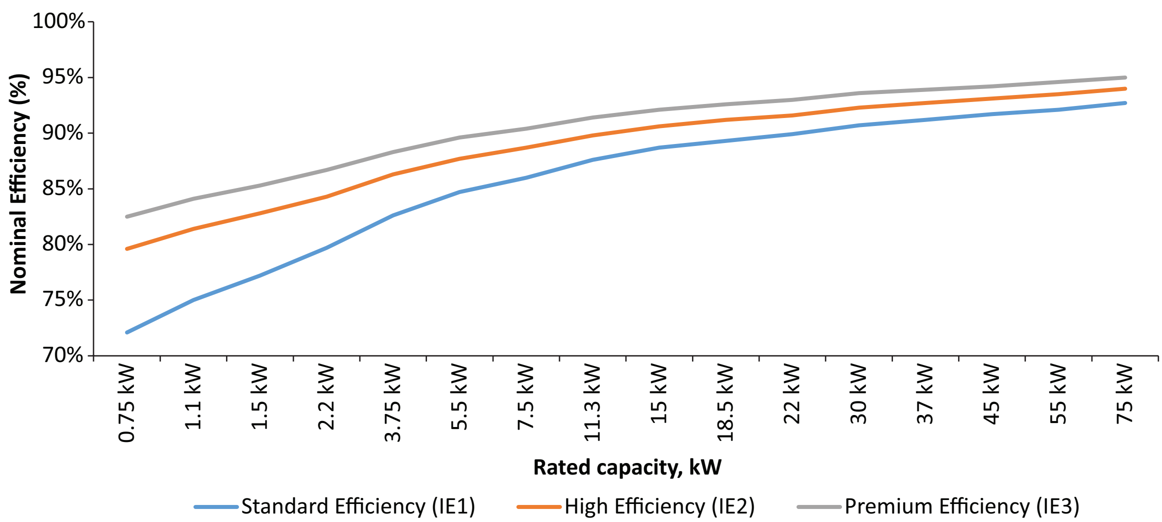


Figure 25: Efficiencies of electric motors (as per IEC standard)

As seen in Figure 8, the difference between the efficiencies of the three classes of the motor varies with their capacity. The difference in the efficiencies between the IE1 and IE3 classes is more significant for lower capacity motors (0.75–7.5 kW) and medium capacity motors (11–30 kW) as compared to the higher capacity motors (37–75 kW). This indicates that the potential for saving energy is higher for low and medium capacity motors than it is for higher capacity motors.

Considering that the low and medium capacity motors constitute more than 90% of the total number in operation, it can be stated that the overall potential for energy saving across electrical motors is significantly high.

Typical energy saving potential and payback periods for replacement of low, medium, and high capacity motors are given in Table 5.

Table 5: Cost–benefit analysis of replacing standard motors with IE3 motors

Parameters	Case study – 1		Case study - 2		Case study - 3	
	IE-1	IE-3	IE-1	IE-3	IE-1	IE-3
Rated capacity (kW)	5.5		18.5		45	
Design Efficiency (%)	84.7	89.6	89.3	92.6	91.7	94.2
Corrected (%) (IS15999)	83.22	89.6	88.02	92.6	90.67	94.2
Electricity consumption (kWh/Yr) [16]	19,331	17,955	61,478	58,437	1,45,169	1,39,729
Electricity saving (%)	7.12"%		4.95"%		3.75%	
Annual cost saving (₹./Yr)	10,447		23,079		41,289	
Investment for IE3 Motor (₹)	14,575		49,025		1,19,250	
Simple payback period (Yr)	1.4		2.1		2.9	

It is therefore recommended to replace the existing standard efficiency IE1 and IE2 motors with premium efficiency class (IE3) motors: specifically, the motors which are lowly loaded and/or rewound more than twice, across the utility and process applications, The average energy saving potential for the entire range of capacities is estimated to be 5.2%. This measure can bring down the overall energy consumption of electrical motors by about 2.5 million units of electricity annually across the 100 MSME units. This will not only save about ₹1.9 crores[17] of the production cost of the industrial consumers annually but will also reduce CO_2 emissions[18] by 2000 tonnes per year.

4.3.2 Air Compressors

4.3.2.1 Introduction

Compressed air is one of the most essential utility requirements of many manufacturing units, because it directly serves processes and applications like pneumatic tools, pneumatic controls, cylinders for machine actuation, etc. Although compressed air is an indispensable utility and air compressors are among the highest energy consuming systems, they are usually ignored until something goes wrong with the machines, or the compressors fail to stay up with rising air/pressure demand.

Both reciprocating and screw type air compressors are commonly used among SMEs. While the larger units use rotary screw type compressors, the smaller units use tank-mounted reciprocating units. For practical purposes, the most effective indicator to compare the air compressor efficiencies is the specific power consumption (SPC), i.e., kW/volume flow rate measured in cubic feet per minute (cfm). The SPC of different air compressors is shown in table 6. As can be seen, there is good potential for energy saving by replacement of reciprocating compressors by screw compressors or by the adoption of the latest Permanent Magnet Synchronous Motor (PMSM) compressor technology.

[17] 1 crore = 10 million

[18] Grid emission factor = 0.81 kg/kWh

Table 6: Typical efficiencies of different types of air compressors

Compressor type	Specific power consumption (kW/cfm @ 7 bar)
Reciprocating[19]	0.20–0.25
Rotary screw[20]	0.18–0.21
PMSM screw	0.15–0.16

4.3.2.2 DENSITY

A total of 124 air compressors were covered under the assessment study. Reciprocating type air compressors were the most common (56%). Rotary type screw compressors accounted for the balance (44%). Most industries require low to medium pressure compressed air between 5.5–10.5 kg/cm^2 (g). However, high pressure compressed air up to 22 kg/cm^2 (g) is required by plastic industries using blow moulding machines.

Tank-mounted reciprocating air compressors are commonly used by units having intermittent requirements of low pressure compressed air. Rotary screw type air compressors are preferred by most continuous process industries.

It was observed that the generation pressure of the air compressors is kept between 7.5–10 kg/cm^2, even when the maximum pressure requirement in the process is below 5.5 kg/cm^2 leading to wastage in energy. Hence, considerable energy saving is possible by simply adjusting the compressed air generation set pressure. Screw compressors are designed to operate at more than 80% load for efficient performance. It was observed that these compressors were operating at 50–60% of their rated capacity. There is potential for energy saving in the screw compressors by the adoption of variable frequency drive (VFD)[21] or by the adoption of PMSM air compressors.

The average running time of air compressors varies from 4 hours to 18 hours in SMEs. The capacity of air compressors installed in the SMEs ranges between 1.1–45 kW. The capacity-wise average density of air compressors in the three utilities is depicted in Figure 26.

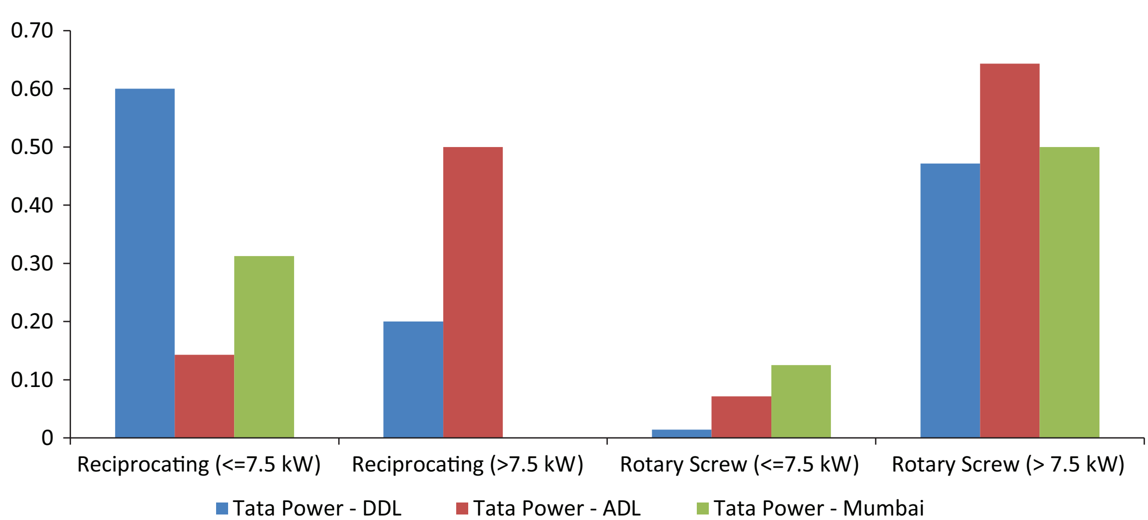


Figure 26: Density of air compressors in industrial consumer categories

[19] The compressor rating considered for arriving at SPC of compressor is 2.2 kW to 11 kW @ 7 kg/cm^2 (g) pressure

[20] The compressor rating considered for arriving at SPC of compressor is 0.37 kW to 22 kW @ 7 kg/cm^2 (g) pressure

[21] Also known as variable speed drive (VSD) or inverter-based

As can be seen from the figure, reciprocating compressors were more common for small capacities (2.2–7.5 kW) up to 30 cfm, whereas the screw compressors are common for higher capacities (11– 37 kW) between 30–200 cfm.

The capacity-wise installed number of air compressors in the three utilities is given in Figure 27.

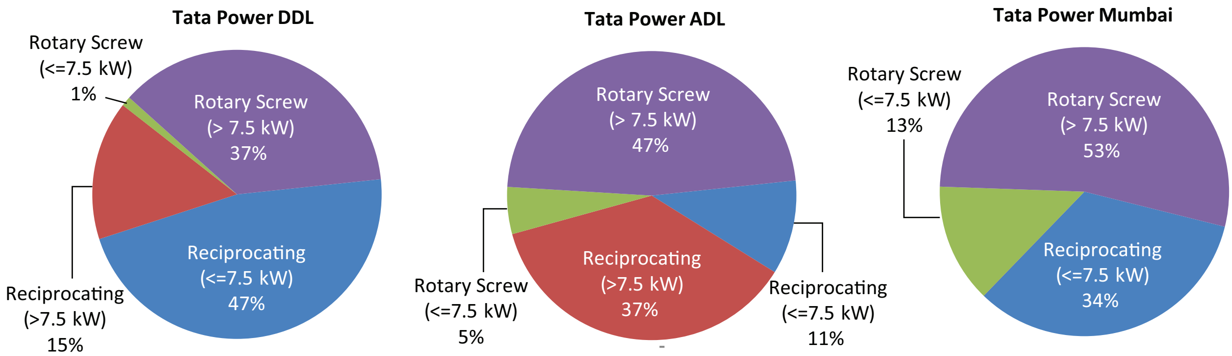


Figure 27: Capacity-wise share of air compressors

As can be seen from the figure, reciprocating air compressors are common among the units in Delhi, whereas the rotary screw air compressor is more common among units in Ajmer and Mumbai.

4.3.2.3 Performance assessment

During the study, performance assessment of air compressors was carried out to identify the potential for energy savings. The assessment broadly focused on the following aspects:

- Loading assessment (i.e., capacity utilization) of the compressor
- Design and operating SPC
- Annual electricity consumption

Capacity utilization (loading assessment)

To assess the capacity utilization of the compressed air system, data on the load hours and unload hours of the air compressors were collected, along with the set pressure range and requirement at the utilization end. An air compressor operates in the load and unload mode of operation throughout the day. For example, a compressor operating with set pressure between 7–8 kg/cm^2(g) means that the compressor unloads at 8 kg/cm^2(g) and loads at 7 kg/cm^2(g).

The loading of an air compressor and actual demand for compressed air in the plant was assessed using the formulae:

$$\text{Loading of air compressor (\%)} = \frac{\text{load hours} \times 100}{\text{(load hours+unload hours)}}$$

$$\text{Compressed air demand (cfm)} = \text{Rated capacity} \times \frac{\text{load hours}}{\text{(load hours+unload hours)}}$$

The actual demand for compressed air in the plant was often below 70% of the rated capacity of the compressor. During the unload operation, the compressor consumes around 30–35% of the full load power without delivering any output. If the air demand fluctuates heavily, the adoption of VFD is recommended. A VFD compressor can maintain the desired pressure and volume of air by increasing or decreasing the speed of air compressors with reduced power consumption.

As a compressor consumes more power at higher pressures, it should not be operated much above the maximum pressure requirement at the utilization end. As a rule of thumb, reduction in the delivery pressure by 1 kg/cm^2(g) reduces the power consumption by 6–10%. Operating air compressors at optimum pressure has the added advantage of reducing air leakages in the network.

Specific power consumption

The operating SPC (kW/cfm) was calculated based on the actual motor power consumed (kW), actual pressure, and air delivery (cfm) mentioned in the nameplate. The operating SPC was then compared with the design SPC provided by the manufacturer to estimate the deterioration in performance.

In most cases, the operating SPC of the air compressor was found to be higher than the design values. For such cases, replacement of reciprocating compressors (2.2–22 kW; 8–95 cfm; rated pressure ~12 bar) with screw compressors (2.2–18.5 kW; 10–100 cfm; rated pressure ~ 8.5 bar) was recommended. Similarly, replacing under-loaded, higher-SPC screw compressors (5.5–37 kW; 22–195 cfm; rated pressure ~ 8.5 bar) with screw compressors (5.5–30 kW; 25–200 cfm; rated pressure ~8.5 bar) with IE4 efficiency class motor and VFD system was proposed. The specific power consumption of different types and capacities of air compressors is given in figure 28.

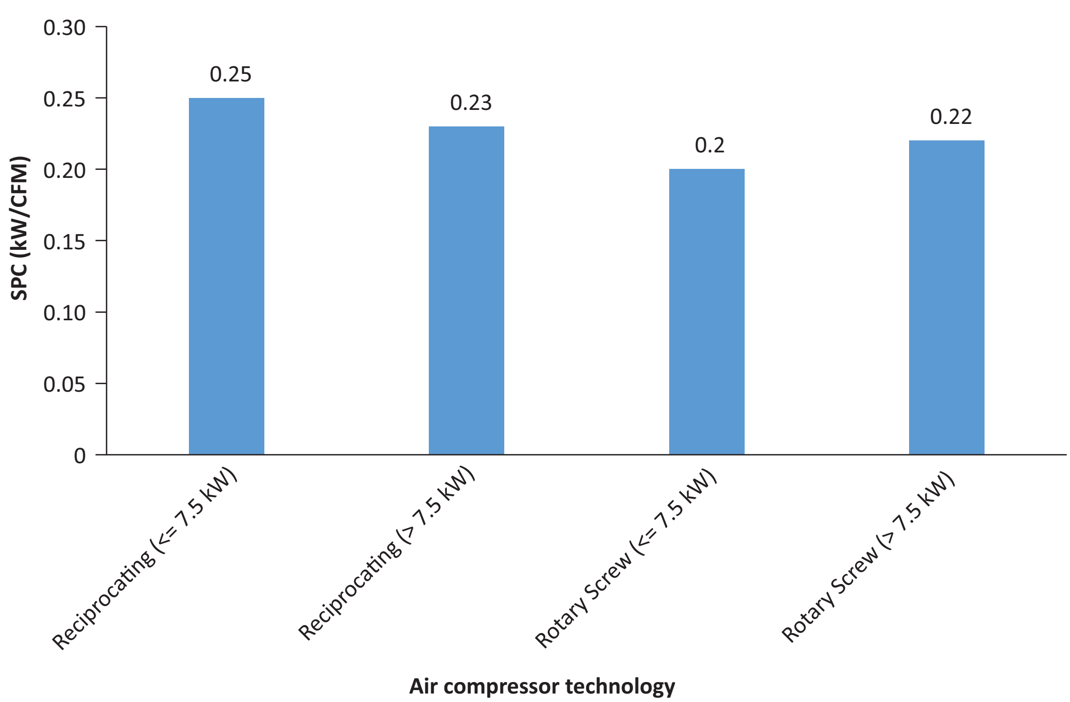


Figure 28: Specific power consumption (SPC) of air compressors

Compressor power consumption

The annual power consumption of the air compressor was calculated from the power input during load and unload of the compressor, and the loading and unloading hours. The cost of running the compressor was then estimated by multiplying the kilowatt-hours used by the rate charged by the utility.

PMSM Air Compressor

Rotary screw type air compressor fitted with IE4 (PMSM) motor and VSD offers

- **Reduced energy consumption by a staggering 50% on average**
- **Best-in-class screw element with longer male rotor, high volumetric efficiency.**
- **Permanent magnetic electric motor: thus, no bearing, no lubricant and no maintenance, 100% transmission.**
- **Unique design for inverter operation to avoid under-capacity losses and help to improve system efficiency over operating speed ranges**

Replacing inefficient air compressors with energy efficient air compressors not only leads to a considerable reduction in electricity consumption but also lowers operation & maintenance (O&M) cost of the consumables.

4.3.2.4 Energy efficiency measures

The difference between the design efficiency of compressors across various capacities is apparent from Figure 28. The compressors installed in the workshop are designed to 0.185–0.25 kW/cfm whereas the actual power consumption of the compressors was estimated to be in the range of 0.195– 0.275 kW/cfm.

Further, the difference in the demand and installed capacity of the compressed air generation increases the power consumption of the unload operation. In normal plant operation, the actual air requirement of the respective areas is less than the designed capacity of the operational compressor. As a consequence, after achieving the set pressure (cut-off), the compressors remain in the unload mode till the system pressure drops due to compressed air consumption in the plant and reaches the set pressure (cut-on) value. The unload power consumption of the compressor is estimated to be 30–40% of the total electricity consumption.

Replacing inefficient reciprocating compressor with energy efficient air compressor

To improve the efficiency in the tiny and small units using small capacity tank-mounted reciprocating type air compressors: the existing compressors may be replaced by energy efficient reciprocating compressors with premium efficiency class (IE3) motor, or by rotary screw type air compressors of similar capacity.

In many installations, the use of air is intermittent. This means the compressor will be operated on a low load or no load condition, which increases the SPC. Hence, for optimum energy consumption, a proper compressor capacity control should be selected. The nature of the control device (VFD, etc.) depends on the function to be regulated.

Replacing conventional screw air compressors with PMSM air compressors

It is recommended to replace the fixed speed rotary screw type air compressors with PMSM type VFD enabled air compressors. The addition of of VFD with air compressors enables the system to regulate (reduce/increase) the speed of the compressor as per the plant's compressed air requirement. The use of variable speed mechanism may completely avoid the unloading condition and save unload power consumption.

With the adoption of different energy conservation measures, the comparison of savings is given in Figure 29.

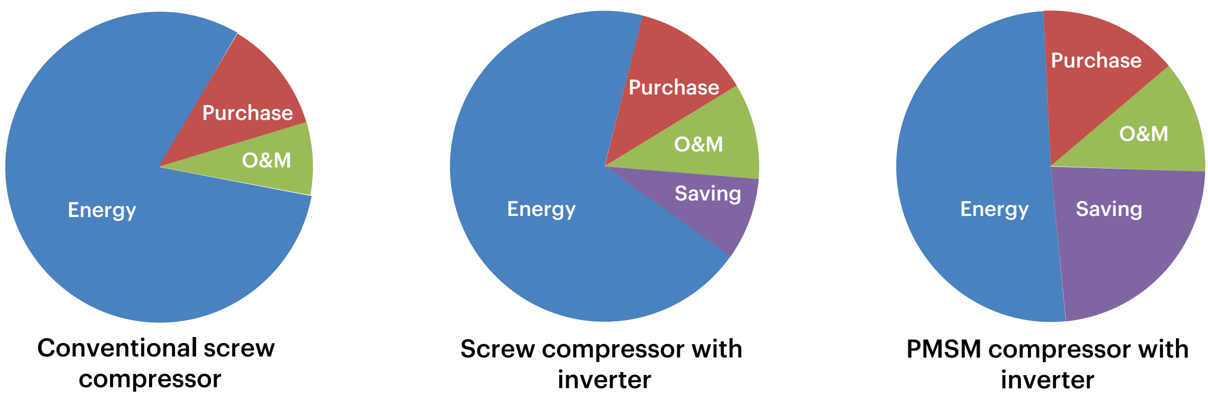


Figure 29: Cost comparison of different technologies of air compressors

The analysis of the information and operational data gathered from the assessment studies and literature surveys clearly shows huge untapped energy efficiency potential in the air compressors system. Around 26% of electricity use in the pneumatic applications could be saved cost-effectively, which would reduce total industrial electricity demand by about 1.6%.

Typical energy saving potential and payback periods for replacement of inefficient and fixed type air compressors are given in Table 7.

Table 7: Cost–benefit analysis for energy efficient air compressors

Parameters	Case study - 1		Case study -2	
	Reciprocating type	Rotary screw	Fixed speed rotary screw	PMSM air compressor with inverter
Rated capacity (kW)	5.5		22	
Electricity consumption (kWh/Yr) (@ 4555 hrs/Yr)	16,284	11,773	65,137	48,852
Electricity saving (%)	27.7%		25%	
Annual cost saving (₹/Yr)	32,703		1,18,060	
Investment of EE compressor	82,500		4,40,000	
Simple payback period (Yr)	2.5		3.7	

4.3.3 Lighting

4.3.3.1 Introduction

The lighting system of an industry is an integral and significant part of the entire electrical load, yet often neglected because of its lower power consumption compared to other industrial loads. An efficient lighting system could save a substantial amount of energy with relatively low investment. The industrial lighting system can be classified into two broad categories (Figure 30):

- Conventional Lighting, which includes fluorescent tube light (FTL), mercury vapour lamp (MVL), sodium vapour lamp (SVL), compact fluorescent lamp (CFL), incandescent lamp (ICL), etc.
- Energy efficient lighting, which includes LED bulbs, LED tube lights, and LED floodlights.

Figure 30: Types of lighting in industries

4.3.3.2 Density

The energy efficiency study covered around 7000 lamps and luminaires across the 100 MSME units. The average number of lamps installed per SME was found to be 70. The lighting load of the units typically varies between 2–8% of the total load of the industry. Both conventional and energy efficient lighting systems are in use in industries. These include both conventional and energy efficient lighting systems.

The usage of the illumination system varies between 8–12 hours per day among industries working in two shifts, and 12–14 hours per day among industries working in three shifts. The operating pattern of lighting across the three utilities was found to be almost the same. Figure 31 shows the typical load pattern of lighting for industrial consumers.

As can be seen from the figure, the lighting load is high in the morning and late evening hours for industries operating in two shifts. As is expected, the lighting load continues to be high during the night period for industries operating in three shifts. The density of the various type of lamps installed in the industries of the three utilities is given in Figure 32.

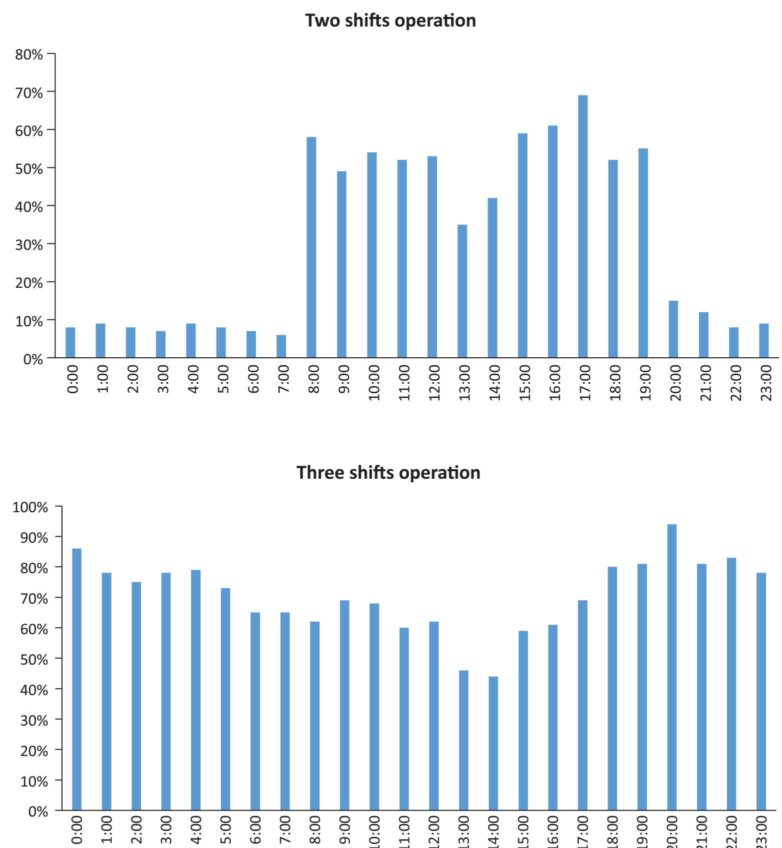


Figure 31: Operating pattern of illumination system in industries

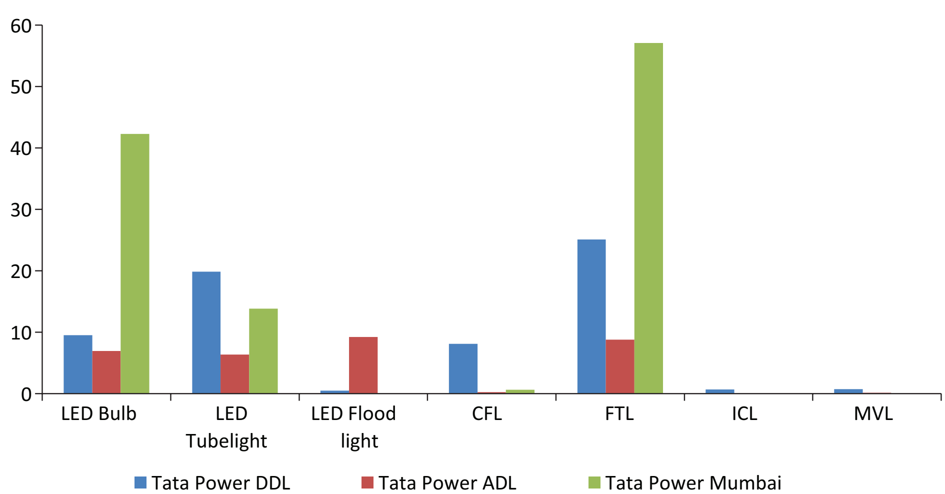


Figure 32: Density of different types of lamps among industrial consumers

It can be observed that the density of FTLs is the highest among industrial consumers. This is followed by the density of LED bulbs and tube lights. The density of CFLs was found to be higher in Delhi.

It was observed that more than half of the total number of lamps in use is of conventional type. For example, FTLs have a share of 43% compared to 19% share of LED tube lights, even though LED tube lights consume only about half the power consumed by the former. CFLs have a share of 4% while LED bulbs have a share of 28%. The share of old and inefficient lamps like ICLs, MVLs, and SVLs is about 1%. The utility-wise share of the different types of lamps installed by the industrial consumers is given in Figure 33.

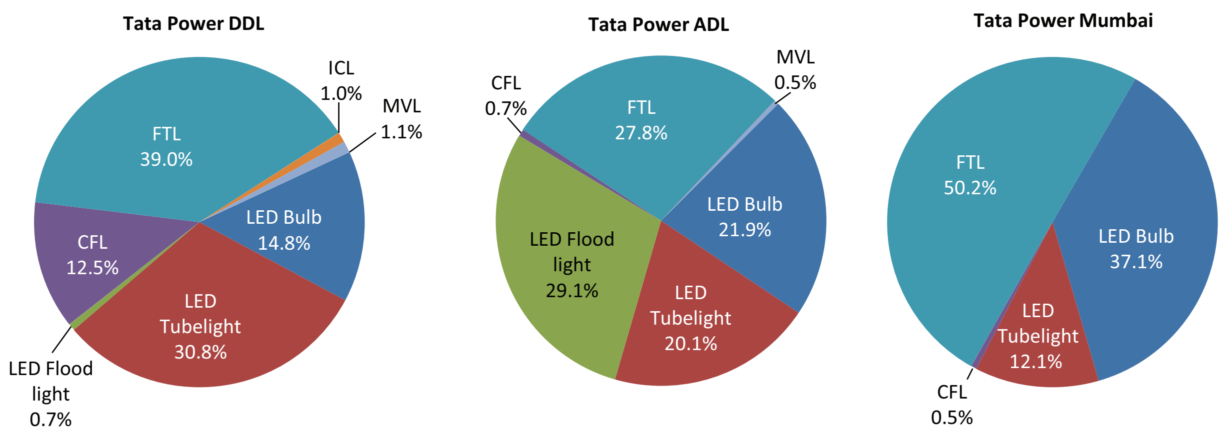


Figure 33: Shares of different types of lamps

4.3.3.3 Performance assessment

A detailed performance assessment of different types of lights was done under the study. The findings reveal that there is a significant potential to save power in industries by replacing conventional lighting systems with energy efficient lighting systems.

The basic specifications of the different types of lamps and lighting installed in the industrial consumer category are given in Tables 8 – 10.

Table 8: Basic specifications of fluorescent lamps/lighting

Parameters	CFL	FTL (T8/T12)	FTL (T5)
Rated wattage (W)	11–48	36–40	28
Ballast power (W)	-	8–12	2
Average life (hours)	6000–15000	7000–15000	7000–24000
Efficacy(lumens/W)	50–80	55–80	80–100
Purchase cost	Moderate	Low	Moderate

Table 9: Basic specifications of LED lamps/lighting

Parameters	Bulb	Tube light	Bay/flood light
Rated wattage (W)	7–18	18–22	28–250
Ballast power (W)	-	-	-
Average life (hours)	Up to 50,000	25,000–55,000	15,000–35,000
Efficacy(lumens/W)	50–80	55–80	80–100
Purchase cost	Moderate	Low	Moderate

Table 10: Basic specifications of HID and ICL lamps/lighting

Parameters	ICL	HID (MVL)	HID (SVL)
Rated wattage (W)	60–200	50–250	75–250
Ballast power (W)	-	25–55	20–40
Average life (hours)	Up to 1000	Up to 22,000	Up to 18,000
Efficacy(lumens/W)	10–14	35–65	85–120
Purchase cost	Low	Low	Moderate

The efficacy of light sources (lumens per watt) indicates the efficiency with which a light source converts power into light. For example, at 10 lumens/W, a 100-W ICL bulb is not very efficient as most of the energy is lost as heat.

The efficiency of CFL bulbs in converting energy into light falls between that of incandescent and LED bulbs. As LED bulbs continue to improve, CFL bulbs will likely be phased out.

The literature survey and study of the research work in the field of lighting technologies revealed that LED lamps produce the least UV radiation and IR radiation compared with the other lighting device. Therefore, the radiation losses in LED lamps are almost negligible; the only energy loss is the heat loss. Figure 34 shows the energy losses in the commonly used lighting devices.

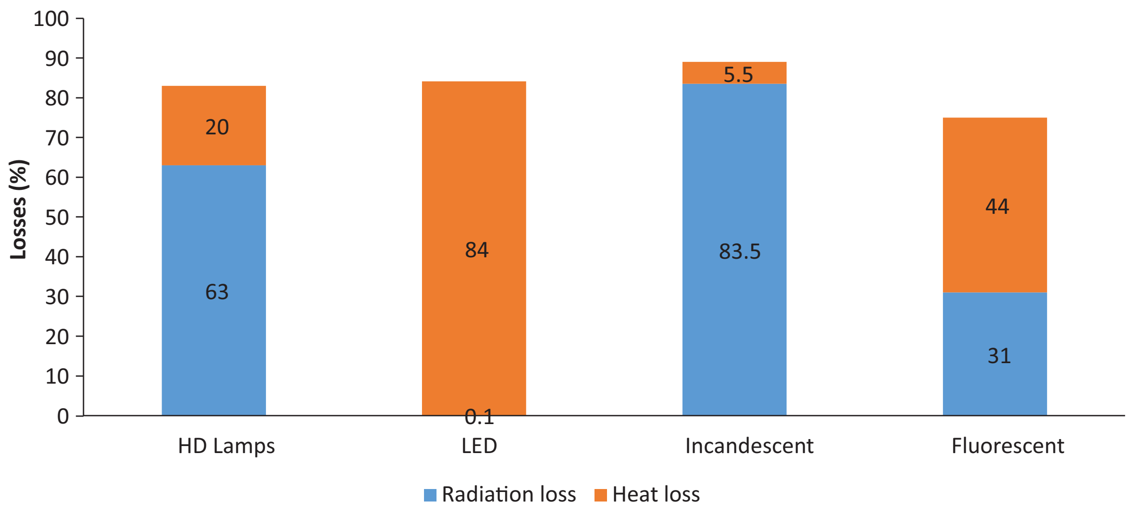


Figure 34: Energy losses in different types of lighting devices

The efficiency of incandescent lamps varies from 8–14%; fluorescent lamps from 24–26%; HID (mercury) lamps from 13–22%; HID (metal halide) lamps from 6–36%; and HID (sodium) lamps from 13.7–42.7%.

Another indicator to assess the lamp is the colour rendering index (CRI), rated from 0 to 100. CRI is used to describe how the light source makes the colour of an object appear to the human eye. The higher the CRI rating, the better the lamp—because the colour seen is closer to the actual colour of the object. Table 11 shows the CRI index for different kinds of lighting.

Table 11: CRI index for different lighting types

Light sources/type	CRI
Fluorescent lamp	52–95
Incandescent lamp	~100
HID (mercury)	15–55
HID (metal halide)	65–80
HID (low pressure sodium)	~0
HID (high pressure sodium)	22–75
LED	80

4.3.3.4 Energy saving potential

The most widely installed linear light source technology in the industrial consumer category is FTL, available in three main variations, namely T-12, T-8, and T-5. The rated wattage of the FTL (T-8) and FTL (T-12) is 36 W and 40 W respectively. In addition to the light source, the ballast consumes around 8–12 W. On the other hand, the LED tube light consumes 18–22 W to deliver almost the same lumen output.

Similarly, the point light sources, i.e., CFLs, and ICLs, are inefficient lighting technologies compared to the present-era LED bulbs. The LED bulb consumes only 15% of electricity as compared to ICLs, and 60% of electricity as compared to CFLs, to deliver the same light output. The details of the existing lighting systems used in the industries and their possible replacement by energy efficient lighting are provided in Table 12.

Table 12: Suggested replacements of existing lighting by energy efficient lighting

Existing lighting		Proposed lighting		Saving potential (%)
Lamp type	**Rated watts**	**Lamp type**	**Rated watts**	**(%)**
FTL (T-12)	52	LED Tube Light	18–22	40–58
FTL (T-12)	44			
FTL (T-12)	30			
CFL (Short)	11	LED Bulb	7–11	36–85
CFL (Long)	18			
ICL	60			
HID (MVL)	190	LED Bay/flood	50–125	45–60
HID (MVL)	110			

LED lighting technology has proven its benefits, as evidenced by the fact that the demand for LED lighting has picked up remarkably in India since 2014. Presently, LED technology is affordable in comparison with old generation lighting (i.e. FTL, ICL, etc.). However, the usage of fluorescent lights (FTLs and CFLs) and incandescent bulbs (ICB) is still high. LED technology has advantages in the following areas;

- High efficacy
- Direct light output
- Long life (up to 50,000 hrs)
- No UV or IR radiation
- Wide range of colour rendition
- Mercury-free

The replacement of conventional lamps by LED lamps will bring electricity savings in the range of 36–85%. Considering this high energy saving potential, the adoption of energy efficient lighting system is the need of the hour. Table 13 shows the energy and cost savings that LED lamps bring in the replacement of other lighting systems.

Table 13: Energy and cost savings brought by LEDs in replacement of other lighting systems

Parameters	Case study - 1		Case study - 2		Case study - 3	
	FTL (T-8)	LED TL	CFL	LED Bulb	ICL	LED Bulb
Rated wattage (W)	44	20	18	9	60	9
Electricity consumption (kWh/Yr)	200	91	82	41	273	41
Energy saving (%)	55%		50%		85%	
Cost saving (₹/Yr)	830		311		1,763	
Investment (₹/lamp)	250		110		110	
Payback period (Yr)	0.30		0.35		0.06	

The table highlights the quick return on investment (ROI) and very attractive payback period (25–130 days) offered by LEDs as a replacement for all types of lamps.

4.3.4 Space Cooling /Air Circulation Fans

4.3.4.1 Introduction

Space cooling and air circulation fans are commonly found in workspaces and office areas of industrial units (Figure 35). Ceiling fans, wall-mounted fans, and pedestal fans are most commonly used in the MSME units. Conventional ceiling fans (1200 mm diameter) are the most common among MSME units. These fans have a power rating between 65–90 W, whereas the pedestal fan (commonly known as 'man cooler') is rated up to 250 W. Despite their significant energy consumption, it was found that fans are usually not accounted while assessing the electrical load of an industrial unit.

Figure 35: Different types of space cooling/air circulation fans in industries

4.3.4.2 Density

Local climatic conditions influence the usage of fans. Delhi experiences composite climate conditions, and therefore fans are used for about eight months in a year (March to October). Ajmer is in the hot and dry climatic zone, and hence here too the operation of fans is similar to Delhi (i.e., March to October). In Mumbai, space cooling fans are operated for about 10 months in a year (February to November). The average daily usage of space cooling fans ranges between 12–14 hours in industries working in two shifts, and between 18–24 hours in industries operating in three shifts.

A total of 628 ceiling fans were found in the 70 industrial units in Delhi, which gives a density of about 9 fans per unit. The average power consumption of these fans was found to be 75 W. The fans are manually switched on and off. There is no monitoring of their operation, and often the fans are left running irrespective of the cooling requirement. These fans were operated for an average of about 13 hours per day, for about 250 days per year. Hence, the average installation of fans (i.e. 9 fans per unit) consumes about 2,194 kW of power annually, which amounts to about ₹16,000 per year in the electricity bill.

The average density of different types of space cooling fans installed in the surveyed industries is given in Figure 36.

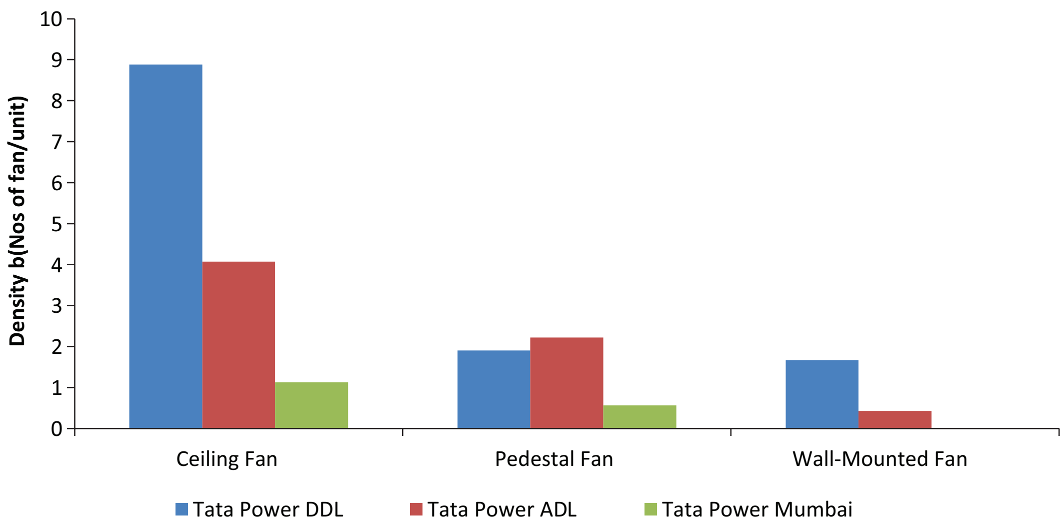


Figure 36: Densities of different types of fans among industries

The majority (99%) of the fans were of the conventional type. Very few units have adopted star-labelled ceiling fans which have rated capacity of 48–55 W, or brushless DC (BLDC) fans which consume only 28 W.

Conventional ceiling fans have the largest share (68%), followed by pedestal fans (22%) and wall-mounted fans (10%) in the units surveyed. The wall-mounted fans are mainly used in the offices and utility shift rooms.

The utility-wise share of the different types of fans installed in the industrial consumer category is shown in Figure 37.

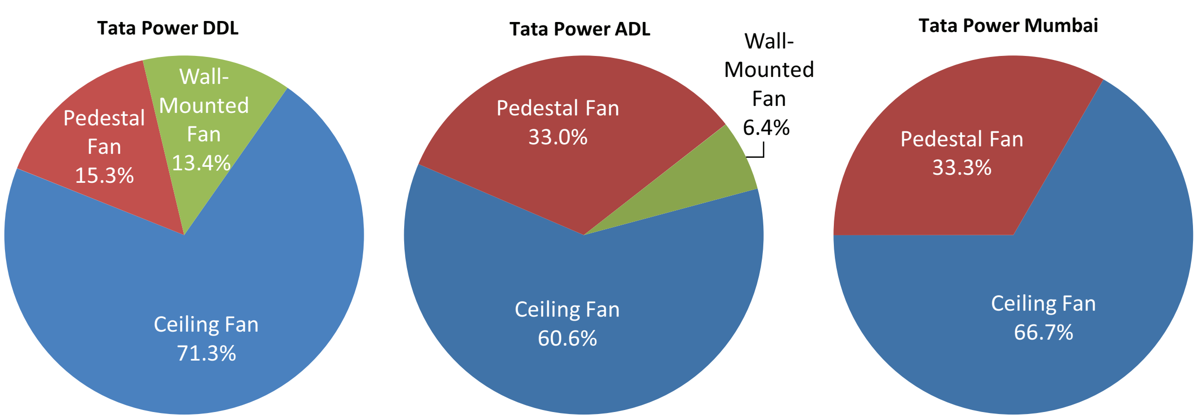


Figure 37: Utility-wise shares of different types of fans

4.3.5 Performance Assessment

The basic specifications of the different types of space cooling/ air circulation fans installed in the industrial consumer category are given in Table 14.

Table 14: Basic specification of conventional space cooling/air circulation fans

Parameters	Ceiling fans	Wall Mounted fans	Pedestal (24")	Pedestal (30")
Rated wattage (W))	65–90	50–55	180	250
Sweep (mm)	1200	400	600	750
Air Delivery (CMM)	230	70	270	400
Speed (rpm)	320	1300	1440	1440
Service value (CMM/W)	2.55–3.5	1.25–1.4	1.5	1.6
Purchase cost	Low	Low	Low	Moderate

The energy performance of space cooling/air circulation fans is typically measured in airflow (measured in cubic metres per minute, CMM) per unit power (W) consumed. In Europe and India, the term 'Service Value' is used to refer to efficacy. The service value of the ceiling fans is highest (~2.55 to ~3.5 CMM/W) among all three categories of conventional fans.

4.3.4.4 Energy efficiency measures

The efficiency (i.e. service value) improvement options for fans mainly focus on the introduction of efficient fan blades, efficient alternating current (AC) induction motors, and the substitution of AC induction motor fans with energy efficient BLDC motor fans. BLDC fans also provide better ambient air quality due to less heating of the motor (75% less than conventional fan).

A comparison[22] of power consumption of the conventional induction ceiling fan with the BLDC fan at different speeds of operation is shown in figure 38.

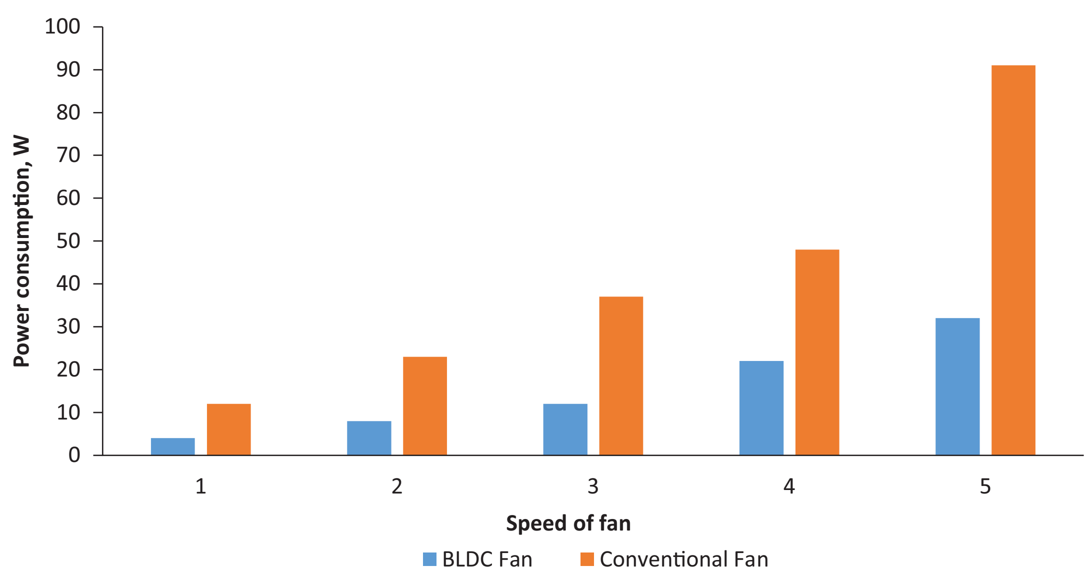


Figure 38: Comparison of conventional fan and energy efficient BLDC fan

[22] Comparison of conventional ceiling fan (1200 mm; 75 W) and BLDC type ceiling fan (1200 mm; 28 W)

Hence, energy efficient BLDC fans are recommended as the best alternative to conventional ceiling fans. The cost–benefit of the replacement is given in Table 15.

Table 15: Cost–benefit analysis of replacing conventional fan with BLDC fan

Parameters	Ceiling Fan		Pedestal Fan		Wall-mounted	
	Conventional	BLDC	Conventional	BLDC	Conventional	BLDC
Rated wattage (W)	77.5	30	215	32.5	52.5	30
Electricity consumption (kWh/Yr)[23]	252	98	699	106	171	98
Electricity saving (%)	61%		85%		43%	
Cost saving (₹/Yr)	1173		4508		556	
Investment (₹/fan)	2250		4500		2250	
Payback period (Yr)	1.9		1.0		4.0	

In addition to savings in energy, there is a potential to mitigate about 100 tonnes of CO_2 per year by opting for BLDC fans among the 100 MSME units surveyed.

4.4 Summary of Technologies and Energy Saving Potential

As described in the earlier section, there is significant potential for industries to minimize energy consumption and save on energy costs through the replacement of old and conventional technology or equipment with new and energy efficient equipment. Table 16 summarizes the existing technologies/ equipment and the energy efficient options available for the industries studied.

Table 16: Summary of energy saving options

S. No.	Existing equipment/ scenario	Proposed equipment/ scenario	Benefits/Advantages
Electric motor			
1	Standard efficiency class motors of capacity 0.12–450 kW	Premium efficiency class (IE3) motors (Standard IS 12615:2018 or IEC: 60034-30)	➢ Reduction in electricity consumption ➢ Reduced O&M ➢ Improved power factor (PF) and hence reduction in distribution losses ➢ Lower working temperatures, and hence longer life
2	Standard efficiency class motors Loaded up to 40% of rated capacity Rewound more than 2 times	Premium efficiency class (IE3) motors loaded between 65–85% of rated load	

[23] Annual operating hours are estimated to be 3150 hours per year

Table 16: Summary of energy saving options

S. No.	Existing equipment/ scenario	Proposed equipment/ scenario	Benefits/Advantages
Air compressors			
1	Reciprocating type air compressors (2.2–22 kW; 8–95 cfm; rated pressured ~12 bar)	Rotary screw type air compressors (2.2–18.5 kW; 10–100 cfm; rated pressure ~8.5 bar)	➢ Operation at optimum pressure; hence, reduced leakages in network ➢ Reduction in electricity consumption ➢ Reduced O&M and consumables
2	Rotary screw type air compressors (5.5–37 kW; 22–195 cfm; rated pressure ~ 8.5 bar) Higher specific power consumption(kW/cfm) Poor loading (<70%)	Rotary screw type air compressors with IE4 efficiency class motor and VSD system (5.5–30 kW; 25–200 cfm; rated pressure ~8.5 bar)	
Illumination system			
1	FTLs & Batten lights (4ft; T-5, T-8 & T-12; electronic & copper ballast)	LED tube-lights & Batten lights (4ft; 18–22 W)	➢ Longer life (~50,000 burning hours) ➢ Reduced electricity consumption (~50%) ➢ Improved PF, and hence reduced distribution losses ➢ Lower heat loss; hence, improved working environment
2	CFLs (11–24 W)	LED bulb/lamp (7–9 W)	
3	MVLs/SVLs (75–150 W; electronic & copper ballast)	LED floodlight/shed light/ bay light (35–75 W)	
4	ICLs(60–100 watt)	LED bulb/lamp (7–9 W)	
Space cooling / air circulation fan			
1	Conventional induction-based ceiling fan (1200 mm; 65–90 W; 200–220 CMM; 300–350 rpm)	BLDC ceiling fan (1200 mm; 28–35 W; 200–220 CMM; 300–350 rpm)	➢ Reduced maintenance and longer life ➢ Reduced electricity consumption (~55%) ➢ Lower heat loss; hence, improved working environment
2	Conventional induction based pedestal fan (400–450 mm; 50–65 W; 65–85 CMM; 1250–1500 rpm)	BLDC pedestal fan (400 mm; 30–35 W; 75–80 CMM; 1250–1350 rpm)	
3	Conventional induction based wall-mounted fan (400 mm; 65–90 W; 65–80 CMM; 1250–1500 rpm)	BLDC wall-mounted fan (400 mm; 30–35 W; >70 CMM; 1250–1350 rpm)	

The other unit-specific energy conservation measures, technologies and solar PV options identified during the assessment studies are provided in Annex 9.

4.5 Consumer Awareness

Awareness on energy efficient products is a significant tool to help purchasers to make more informed decisions about the total cost of acquiring and operating the new equipment, and to modify behaviour (e.g., encouraging the timely repair of equipment by certified technicians).

During the assessment study and stakeholder consultation, data was collected on awareness levels regarding the common equipment/appliances. The analysis of this data reveals that only about 28% of industrial consumers were aware of energy efficient (IE2) and premium efficiency class motors (IE3). The levels of awareness were also low regarding energy ratings of other appliances like air compressors, ceiling fans, and lighting.

Air compressors are essential components of many industrial processes. However, the selection of an air compressor is typically based on the capacity suggested by the supplier or dealer. As with other appliances, awareness levels were very low on aspects like compressor capacity, operating pressure, and use of VFD (Figure 39).

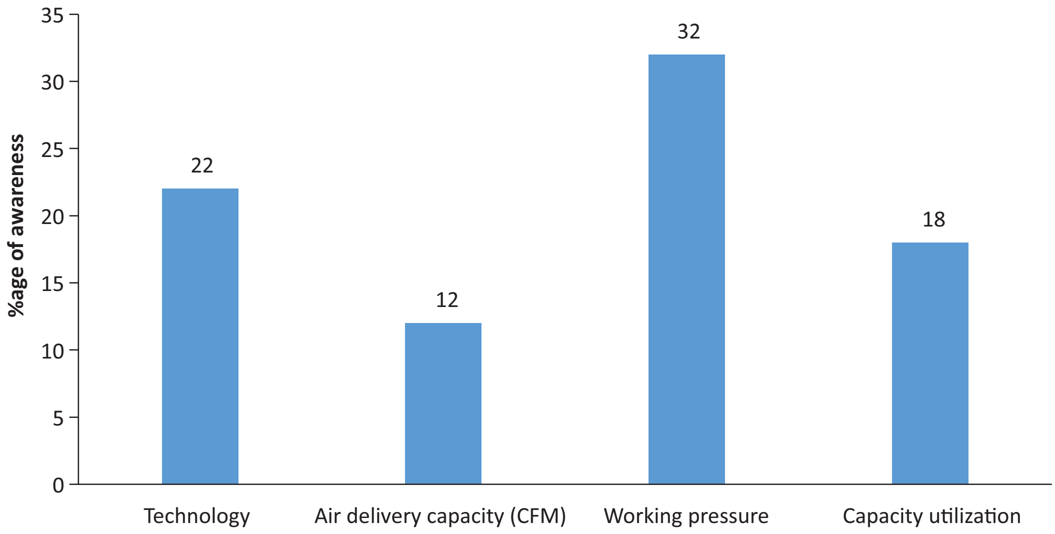


Figure 39: Awareness on air compressors

The major awareness barriers among MSMEs arise from lack of information, coupled with the lack of technical capacity for evaluating the potential savings from energy efficient appliances and systems. For example, although BLDC technology has proven its benefits in the distribution area, the penetration of these energy efficient fans remains low, especially among industrial consumers. Figure 40 depicts the low awareness levels among industrial units in regard to energy efficient appliances.

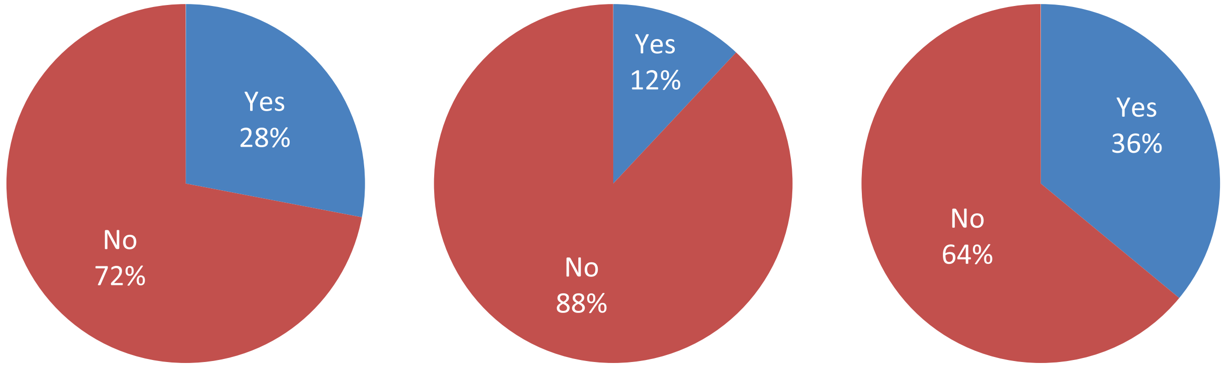


Figure 40: Awareness about energy efficient appliances

5. DEMAND AGGREGATION AND ENERGY SAVING POTENTIAL

Demand aggregation is a critical step in the development of a utility DSM program. As has been discussed under the chapter 'Demand side load research', there are several energy-efficient (EE) technologies that can be adopted by industrial consumers to save energy and reduce their electrical demand.

Aggregation of the identified EE technologies was conducted to estimate the cumulative demand for these technologies among industrial consumers. The aggregation exercise is helpful in estimating the cumulative quantity of these EE technologies that can be purchased or procured in bulk by the utility, so that the cost of the EE technology is brought down through economies of scale. Extrapolation of the results of the sample survey is an important step in estimating the aggregated demand in the entire population. Demand aggregation thus serves the following purposes:

- It helps in estimating the total demand for the new technology among the consumer group in the distribution area of the utility.
- A better understanding is developed of the cumulative demand reduction, energy savings and GHG mitigation potential.
- The utility or ESCO could negotiate a better price for the EE technology if bought in bulk.

Based on the sample energy assessment studies conducted, the aggregated demands for the following EE technologies were estimated.

- **Premium efficiency IE3 electric motors,** to replace low-efficiency (IE2 or less) motors
- **LED lighting systems** to replace conventional lighting such as FTLs (both T5 and T8); CFLs; ICLs; MVLs; etc.
- **BLDC space cooling/air circulation fans** to replace conventional ceiling, pedestal and wall-mounted fans.
- **EE air compressors (PMSM, VFD rotary screw or EE reciprocating)** to replace low-efficiency air compressors.

5.1 Approach

Unlike an examination of the entire population, which would typically yield definitive conclusions, sample surveys yield estimates about characteristics of the broader population along with a degree of uncertainty related to those estimates. This uncertainty exists due to the fact that only part of the population has been measured, and the magnitude of this uncertainty can be influenced by the methodology, techniques, assumptions and calculations used to perform the analysis.

A density-based extrapolation method was used for aggregating demand for the EE technologies among industrial consumers. While aggregating the demand, the specific variables (i.e., technologies, applications, rating, efficiencies, loading factor, running hours, etc.) of each technology were taken into account. The demand aggregation exercise was undertaken for the distribution area under Tata Power DDL where the sample size was sufficiently large. The MSME consumer base and their contract demands which were considered to make the extrapolation are summarized in Table 17.

Table 17: Industrial consumer base and assumptions

S. No.	Parameters	Unit	Value	Remarks
1	Total number of industrial consumers	Nos	70,682	Including services sector, MSME and express feeders
2	Total contract demand	MVA	2,652	Contract demand ranges between 1 kVA–42 MVA
3	Number of MSME units	Nos	14,328	Contract demand ranges between 50–1,500 kVA
4	Total contract demand of MSME units	MVA	1,387	-

After a detailed segregation of each conventional technology based on capacity and type, the extrapolation was conducted for the entire population based on density, population, and demand factor.

The generic formula used for estimating the aggregated demand is as follows:

Aggregated demand = Density × Population × Demand factor[1]

Where:

Density: Ratio of number of equipment (by capacity, type, etc.) to the total number of the surveyed units

Population: Total number of industrial MSME consumers/units in the distribution area

Demand factor: Ratio of the demand of the equipment to total contract demand of the unit

The detailed layout of the model adopted, specific variables, aggregated demand, and energy saving potential for each technology are given in the subsequent sections.

5.2 Electric Motors

The stock data of the installed electric motors, their operational parameters and service history of the units surveyed were collected during the assessment study. Sample measurements of the electric motors were taken to assess the loading pattern (percentage load of rated capacity), nature of load (fixed or variable) and operating hours. Motor rewinding history and other maintenance records were collected from the maintenance records of the units.

Stakeholder consultations helped to understand the barriers to the adoption of EE electric motors in the units. One-on-one meeting were also held with OEMs and local motor maintenance workshops to understand the availability of EE motors and issues in after-sales support.

The density-based demand aggregation model considered a number of variables for estimating the demand for electric motors, which are indicated in Figure 41.

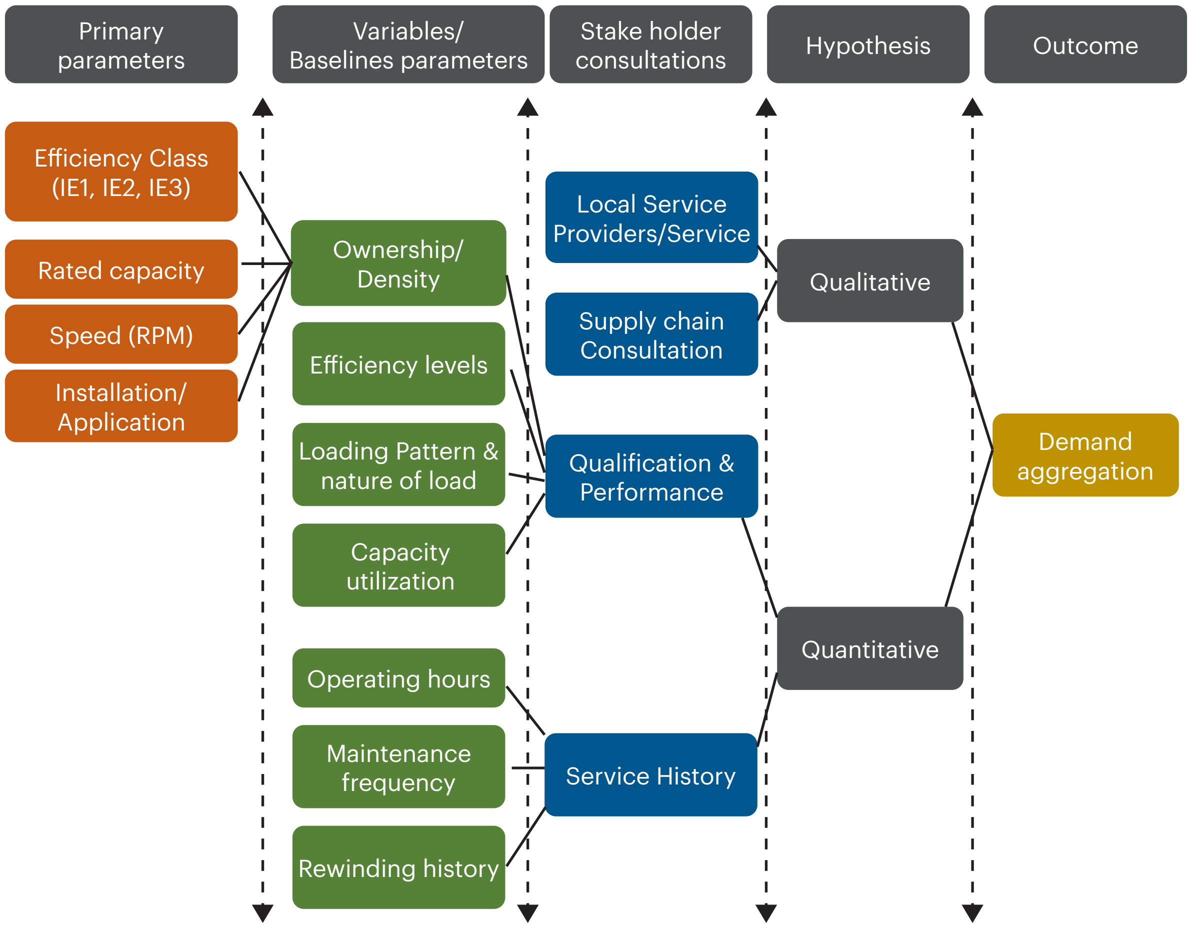


Figure 41: Demand aggregation flow for electric motors

The estimated capacity-wise aggregated demand for electric motors and potential for energy and GHG savings is summarized in Table 18.

Table 18: Aggregated demand for EE electric motors and energy saving potential

Category	Nos of motors	Demand reduction (MW)	Energy saving (MUs/Yr)	Reduction in GHG emission (tCO_2/Yr)
up to 7.5 kW	77,120	20.9	75.0	60,787
7.5–30 kW	31,760	28.1	93.3	75,581
More than 30 kW	8,070	15.6	50.3	40,743
Total	1,16,950	64.6	218.6	1,77,111

Capacity-wise aggregated demand of the electric motors are given in Annex 10.

Thus, there is an aggregated demand for about 117,000 EE electric motors among MSME industries in Delhi. Figure 42 shows the shares of motors of different capacities. As can be seen from the figure, about 93% of these are less than 30 kW. The total potential to save electricity by replacing these motors with premium efficiency class (IE3) motors is about 219 million units, which is equivalent to about 5.2% of the total electricity used by industries.

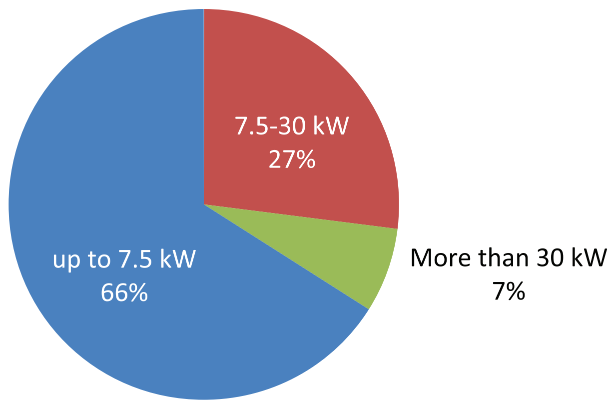


Figure 42: Share of different capacity of motors

Apart from the reduction in electricity consumption, a significant reduction in electricity demand is also envisaged by adoption of the EE technology. The total GHG emissions reduction potential of the measure is about 0.18 million tonnes of CO_2 per annum.

5.3 Lighting

The installation details of each lighting point in the various sections of the factory were collected during the assessment study. The general information of the illumination such as type of lamp (i.e., FLT, ICL, LED, etc.), rated wattage (lamp and ballast), application and lux level were measured and/or collected. Life of the lamps, change history and maintenance record (e.g., failure etc.) were also collected from the units.

The interactions with stakeholders helped in developing a better understanding of the barriers to adoption of EE LED lighting in the units. The impact of the on-going demand-side activities of the utility like 'UJALA'was also assessed during the interactions.

The density-based demand aggregation model considered a number of variables for estimating the demand for EE lighting system which are indicated in Figure 43.

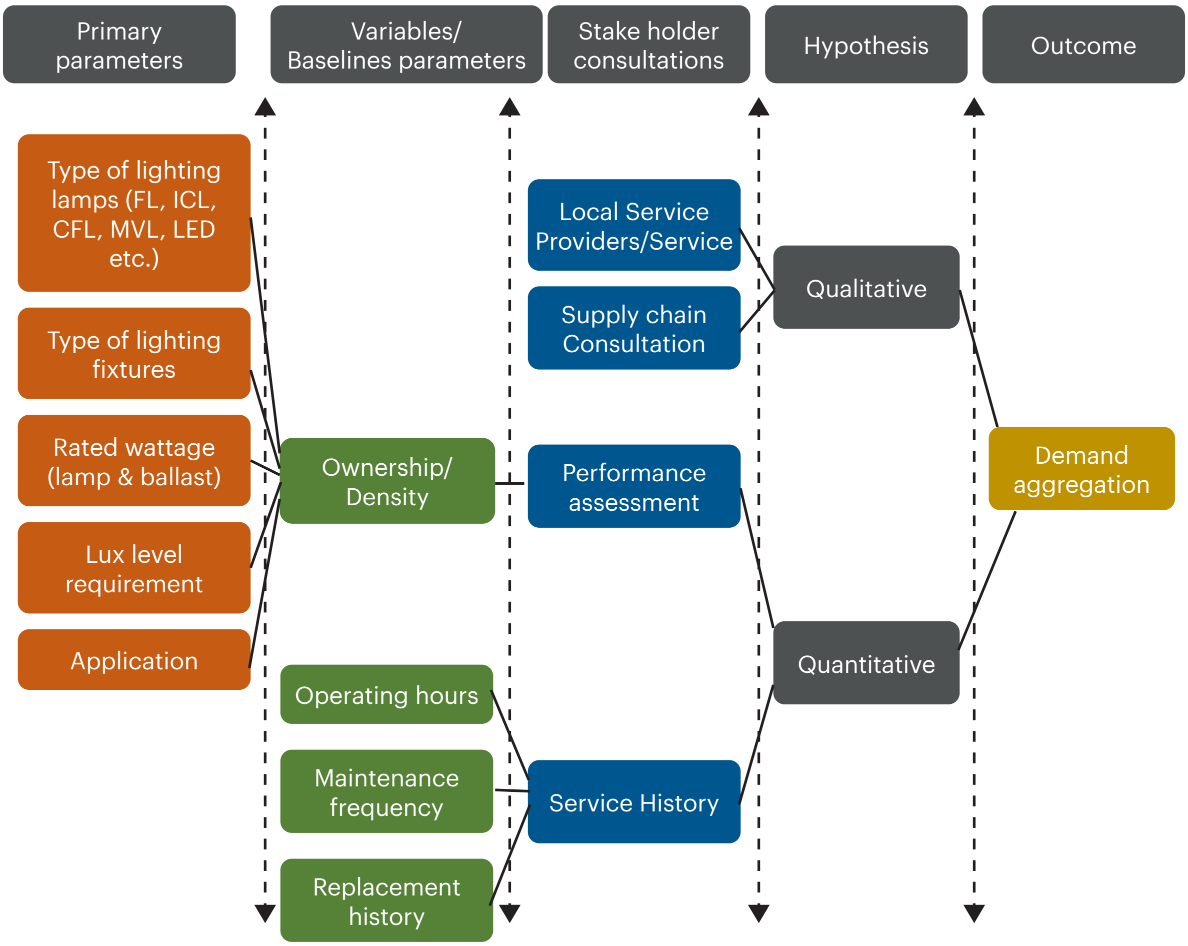


Figure 43: Demand aggregation flow for lighting system

The aggregated demand for LED lights/lamps, and potential reductions in demand, energy consumption and GHG emissions are given in Table 19.

Table 19: Aggregated demand and energy saving potential by adoption of EE lighting system (LEDs)

Category	Nos of lamps	Demand reduction (MW)	Energy saving (MUs/Yr.)	Reduction in GHG emission (tCO_2/Yr.)
LED Bulb	62,794	1.0	4.3	3,515
LED Tube light	1,80,468	4.3	19.7	15,980
LED Flood light	5,139	0.6	2.7	2,180
Total	2,48,401	5.9	26.7	21,675

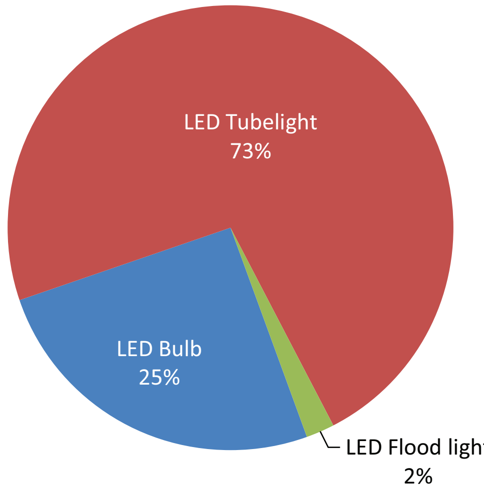


Figure 44: Share of different types of LED lights

Thus, there is an aggregated demand for about 248,400 LED lights among MSMEs in Delhi. The shares of different types of LED lights are shown in Figure 44. As can be seen from the figure, about 70% of demand is for LED tube lights (18–20 W; 4ft) and 28% of the demand is for LED bulbs. The total electricity saving potential of replacing all existing conventional lights by EE LED lights was estimated to be 26.8 million units. This is equivalent to about 41.5% of total electricity consumption in lighting. Apart from the reduction in electricity consumption, a significant reduction in electricity demand is also envisaged by adoption of EE lights. The total GHG emissions reduction potential is estimated to be about 21,675 tonnes of CO_2 per annum.

5.4 Space Cooling/Air Circulation Fans

The details of fans installed for space cooling or air circulation in the workspace in various sections of the industry were collected during the assessment study. The general information on these fans such as type of fans (i.e., pedestal, wall-mounted, ceiling, etc.), and rated wattage, were measured and/or collected. Data on life of the fans, rewinding history and other maintenance history (replacement of capacitor or bearing, etc.) were also collected from the industries wherever available.

The interactions with stakeholders also helped to develop a better understanding of the barriers to adoption of EE fans. The impact of the ongoing demand-side activities of the utility through 'PAVAN'[24] was also assessed through interactions.

The density-based demand aggregation model took into account a number of variables while estimating the demand for EE space cooling/air circulation fans; these are indicated in Figure 45.

[24] National Energy Efficient Fan Programme (http://fan.ujala.gov.in)

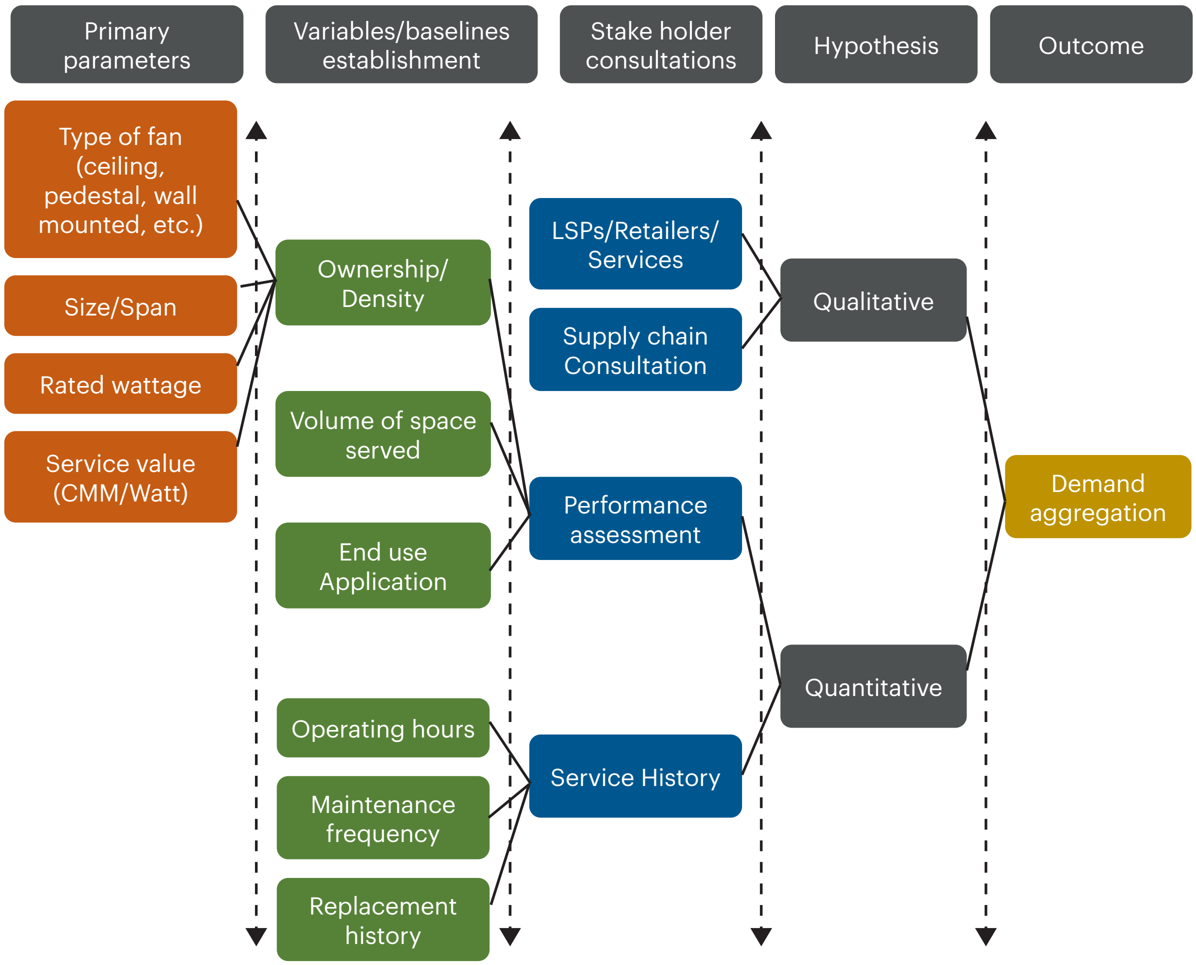


Figure 45: Demand aggregation flow for EE space cooling fans

The aggregated demand for EE BLDC space cooling/air circulation fans and potential reduction in demand, energy consumption, and GHG emissions are given in Table 20.

Table 20: Aggregated demand and energy saving potential for EE BLDC fans

Category	Nos of fans	Demand reduction (MW)	Energy saving (MUs/Yr.)	Reduction in GHG emissions (tCO_2/Yr.)
Ceiling fan	1,06,075	5.0	16.4	13,264
Pedestal fan	22,682	4.1	13.5	10,897
Wall-mounted fan	19,953	0.4	1.5	1,182
Total	1,48,710	9.5	31.4	25,343

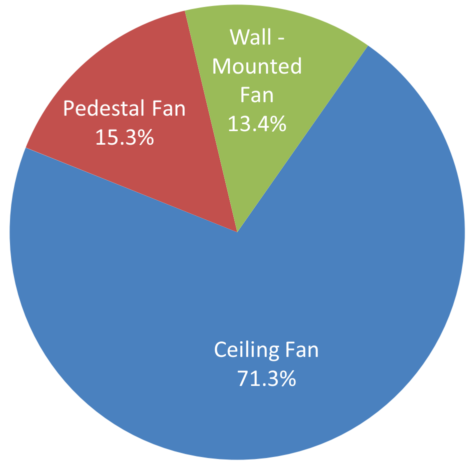


Figure 46: Shares of different types of fans

Thus, there is an aggregated demand for about 150,000 BLDC fans among MSMEs in Delhi. The shares of different types of fans are shown in figure 46. The majority (about 71%) of the demand is for ceiling fans (28–35 W; 1200 mm). The balance of the demand is shared by pedestal and wall-mounted fans The total electricity saving potential by replacing all the conventional fans by BLDC fans was estimated to be about 31.3 million units. This is equivalent to about 68% of total energy consumed by fans in the industries.

Apart from the reduction in electricity consumption, a significant reduction in electricity demand is also envisaged by adoption of EE BLDC fans. The total emissions reduction potential by adoption of the measure is estimated to be about 25,342 tonnes of CO_2 per annum.

5.5 Air Compressors

Data was collected on installed air compressors in the units surveyed. The data included type of air compressor (i.e., reciprocating, screw, etc.), design parameters (i.e., volumetric flow rate, pressure and quality of air), and service history Sample measurements of the free air delivery, compressed air demand, and air leakage were undertaken to assess the specific power consumption, loading pattern (percentage load of rated capacity), nature of end-use applications (fixed or variable) and operating hours. The interactions with stakeholders also helped to develop a better understanding of the barriers to adoption of EE air compressors among the units. Meetings were also held with a few service providers, service workshops and other stakeholders to understand the availability of EE air compressors and after-sales support.

The density-based demand aggregation model took into account a number of variables while estimating the overall demand for EE air compressors which are given in Figure 47.

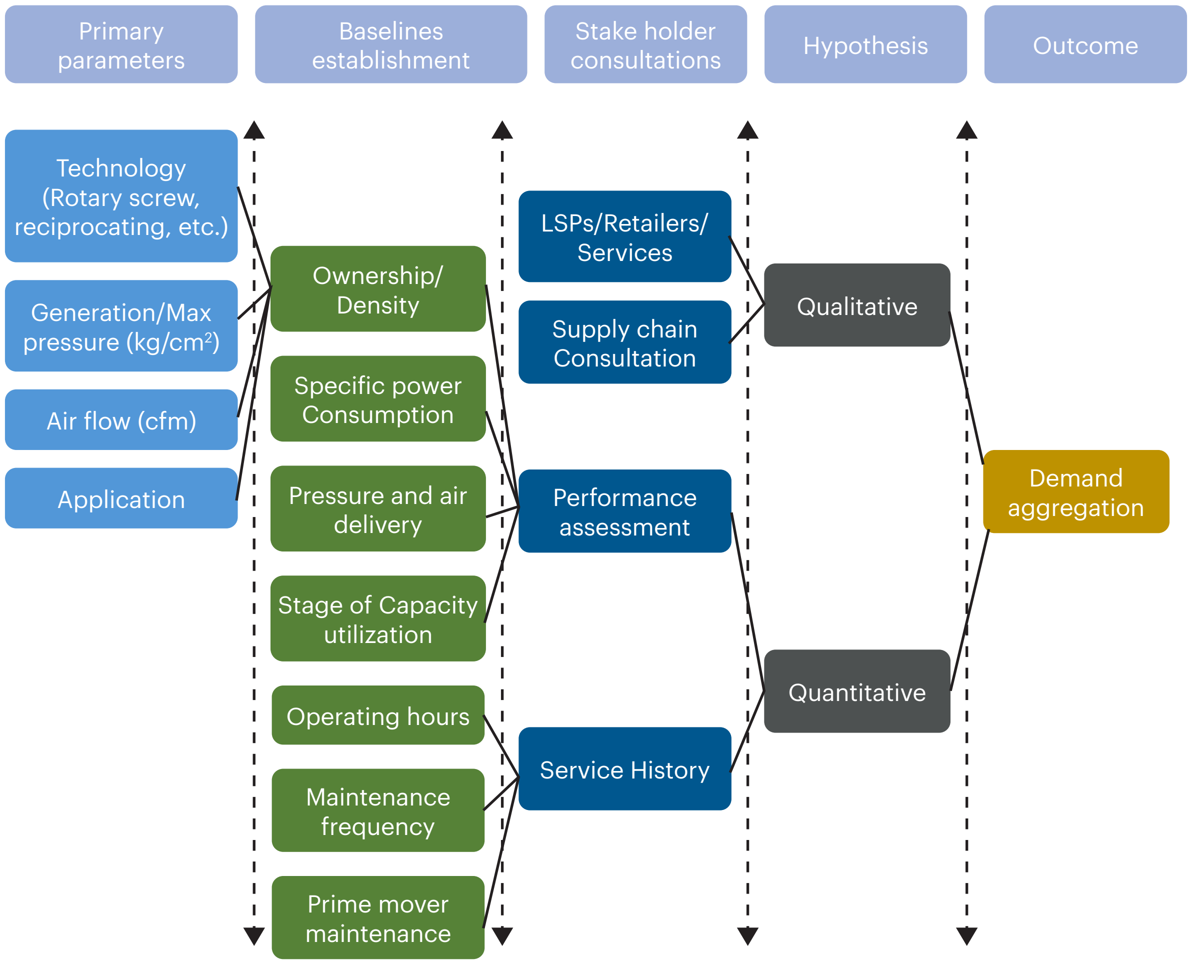


Figure 47: Demand aggregation flow for EE air compressors

The aggregated demand for EE air compressors among units and potential reduction in demand, energy consumption, and GHG emissions are given in Table 21.

Table 21: Aggregated demand and energy saving potential for air compressors

Category	Nos of compressors	Demand reduction (MW)	Energy saving (MUs/Yr)	Reduction in GHG emission (tCO_2/Yr)
EE reciprocating	6,964	6.1	27.8	22,551
VFD rotary screw	1,705	5.4	24.9	20,157
PMSM	7,106	10.8	90.1	72,981
Total	15,775	22.3	142.8	1,15,689

Capacity wise details of air compressors are given in Annex 10.

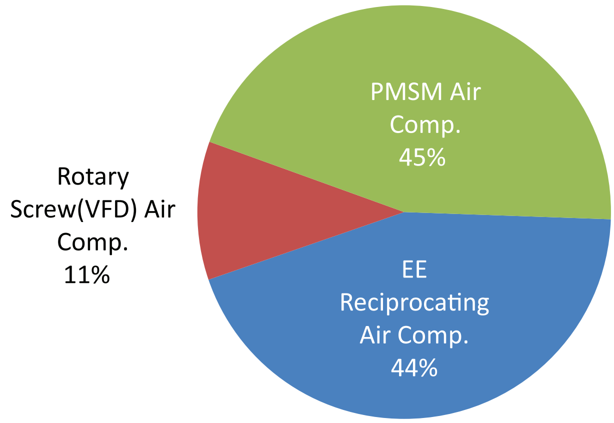


Figure 48: Share of different types of EE air compressors

The aggregated demand for the EE air compressors is estimated to be 15,775. Shares of different types of air compressors are shown in figure 48. About 45"% of the demand is estimated to be for PMSM air compressors (rotary screw type air compressor with IE4 motor) followed by 44% for EE reciprocating air compressors of smaller capacity (tank-mounted with IE3 motor). The total electricity saving potential by replacing the inefficient air compressors with EE air compressors is estimated to be about 142.8 million units. This is equivalent to about 26% of the total energy consumed by air compressors at present. Apart from the reduction in electricity consumption, there will also be a significant reduction in electricity demand by adoption of the measure. The total GHG emissions reduction potential by adoption of EE air compressors is estimated to be about 0.11 million tonnes of CO_2 per annum.

6. BUSINESS MODEL FOR DSM PROJECTS

Apart from best practices, energy efficiency improvements require capital investment. It is well accepted that lack of suitable financing options have hindered implementation of proven energy efficient technologies among industries. Therefore, innovative financing models could play an important role in helping industries address the financial barrier to improve energy efficiency.

The precursors to development of any robust financial models include (a) assessment studies to identify EE technologies which can be adopted in an industrial cluster; (b) shortlisting of the identified EE technologies on basis of replication and energy saving potential; and (c) estimating the aggregated demand of the shortlisted EE technologies. These steps are shown in Figure 49.

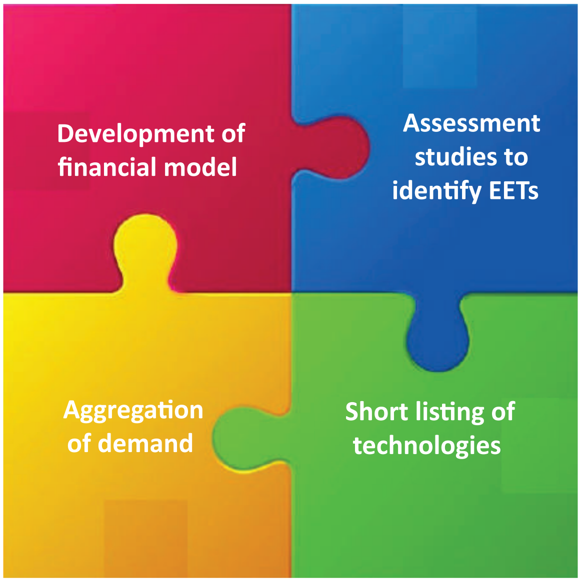


Figure 49: Precursors to development of financial model for EE technologies

All major stakeholders (entrepreneurs, technology suppliers, financial institutions, industry associations, energy efficiency experts and DISCOMS) need to contribute in the development and implementation of innovative financing models. As outlined in the earlier sections, the study has established the potential to achieve significant reductions in electricity consumption among SMEs in the Tata Power distribution license areas studied, by replacing their existing low-efficiency technologies with EE technology options. These technologies offer energy savings ranging from 5.2% to 62% with simple payback period ranging from 0.3 to 3.1 years. These technologies are readily available in the market, and may be introduced among a large number of SMEs cutting across different industrial sub-sectors. Table 22 summarizes the energy savings and cost benefit of the identified EE technologies.

Table 22: Energy savings and cost–benefit of identified EETs

Name of technology	Average Energy saving potential (%)	Monetary saving potential (₹/unit)	Investment (₹/unit)	Payback period (Yrs)
Premium efficiency class (IE3) motor	5.2 (3.7–8.1)	1.2	2.3	2
Energy efficient air compressor (Inverter/PMSM type)	26.3 (25–27.7)	0.75 (0.32–4.4)	2.6 (0.82–4.4)	3.1 (2.5–3.7)
Energy efficient illumination system	57.5 (50–80)	0.3	0.1	0.3
BLDC air circulation fans	62 (43–85)	0.16	0.27	1.6

This energy saving potential presents an opportunity for the utility to promote these EETs on a large scale among its MSME consumers, through a DSM program that combines demand aggregation with bulk procurement so as to reduce the price of each EET, and also present an attractive business venture for the EET providers (typically, large-scale companies/OEMs and their dealers). The challenge is to find an effective business model under which the EETs can be sourced, installed and deployed by MSMEs, while meeting the expectations of all the three primary stakeholders (Figure 50), namely:

- Utility (electricity distribution company)
- Enterprises (MSMEs)
- Technology Providers (energy efficient technology manufacturer, channel partners)

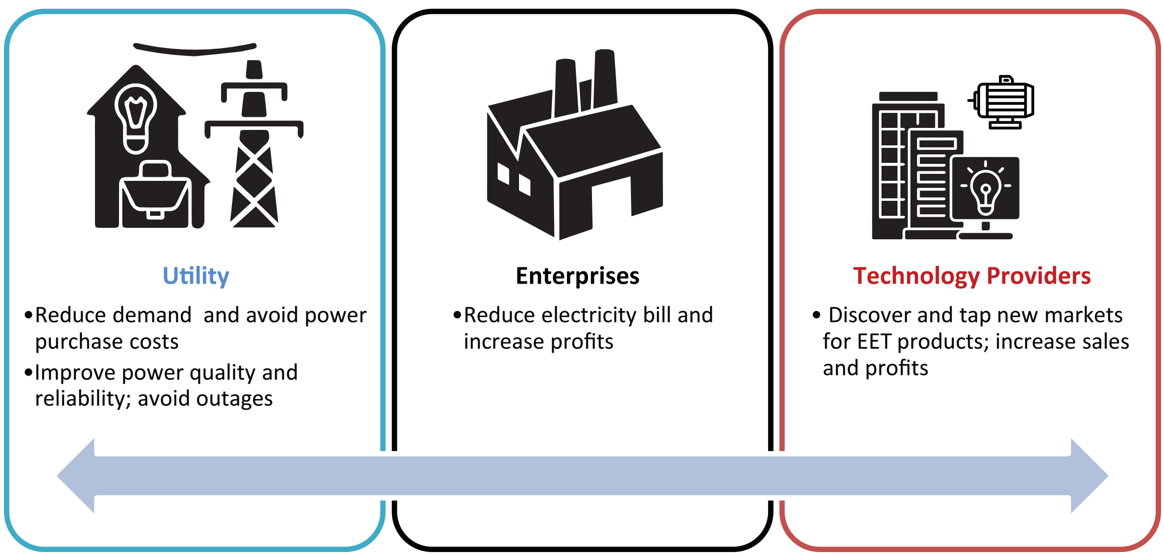


Figure 50: Benefits expected by primary stakeholders from DSM

6.1 Approach

Utilities around the world have attempted a number of approaches to DSM. The common approaches include awareness programs on EE; various financing schemes and incentives; and technical assistance. These approaches yield mixed results (see Table 23). Some utilities have implemented 'comprehensive/ direct installation programs', under which the utility works closely with its consumers to identify, finance and install comprehensive packages of DSM measures, with the utility paying a large chunk of the EET costs. Because of the comprehensive services provided and the low cost to the consumers, such comprehensive/ direct installation programs have generally seen a very high participation rate by consumers (up to 90% in some cases), with consumers also achieving high energy savings. However, these programs require large investments of money, time and effort by the utility.

Table 23: Different approaches to DSM

Approach	Method/Activity	Positives	Negatives
Awareness programs	Educational brochures, etc.	➢ Low cost	➢ Usually results in limited energy savings
	Training programs	➢ High coverage	
Technical assistance	Energy audits (EAs)	➢ Cost–benefit of EE measure can be discussed with consumer	➢ Needs lots of time and resources ➢ Needs follow-up for implementation
Financing	Loans at subsidized interest rates	➢ Useful for high-investment EE measures	➢ Consumers are not keen to take loans, or to share savings with ESCOs for low-investment EE measures
	Promote Energy Service Companies (ESCOs)		
	Rebates on specified EETs	➢ Easy to understand ➢ Higher customer participation ➢ Can promote specific EETs	➢ Cannot promote integrated package of EE measures
Comprehensive programs	EAs to identify package of EE measures and arrange finance for installation	➢ Low cost to the consumer ➢ High savings per consumer	➢ Higher cost for utility ➢ Limited number of consumers can be reached annually
Market transformation	Change the market for particular EETs so that their adoption becomes the norm	➢ Higher energy saving potential ➢ Long-term benefits	➢ Requires lots of effort and coordination among diverse stakeholders ➢ High initial costs ➢ Not suitable for all EETs

In recent years, some utilities have been emphasizing a 'market transformation' approach to DSM. This approach seeks to change the market for particular EE equipment and services so that EE practices become the norm and the utility's involvement in promoting EE is no longer needed. Compared to the other DSM approaches, market transformation programs have the potential to save more energy—because when markets are transformed, consumer participation rates approach 100%. Once markets are transformed, utility involvement and costs can be reduced or eliminated. However, organizing a market transformation effort generally requires a lot of work and coordination of many diverse parties.

6.2 Business Model

Having considered these various approaches to DSM, an innovative business model has been drawn up, in two variants, for a utility-managed DSM program that can effectively promote the large-scale adoption of the five EETs identified under this study. The business model takes advantage of three factors:

➢ The electricity utility has a long and well-established commercial relationship with its MSME consumers.

- A utility-managed DSM program will encourage EET providers to sell their products to MSMEs, because of the assurance that the utility will recover the EET costs from MSMEs through their monthly electricity bills.
- The energy savings from the five EETs can be guaranteed, as these have been tested and validated by the EET manufacturers ('deemed savings').

What is an ESCO?

An ESCO is a business entity that provides a comprehensive package of energy efficiency solutions to its customers on turnkey basis. The ESCO identifies inefficient technologies in an establishment, and procures, installs and commissions the efficient equipment at its own expense. Unlike other entities that provide any or all of these services for a fee, the ESCO links its own earnings to the actual energy savings yielded by the project (through a 'performance-based contract'). Thus, the ESCO takes on the 'risk' typically associated with energy efficiency financing.

Both variants of the business model are designed to operate around the broad principles of an Energy Services Company (ESCO), and address all the key expectations and concerns of the three primary stakeholders in regard to the financing, procurement, installation and use of the EETs (Figure 51). In Model A, the ESCO is a separate business entity, while in Model B; the utility itself assumes the role of an ESCO. The difference in the two model designs is based on the characteristics of the EETs, as explained below.

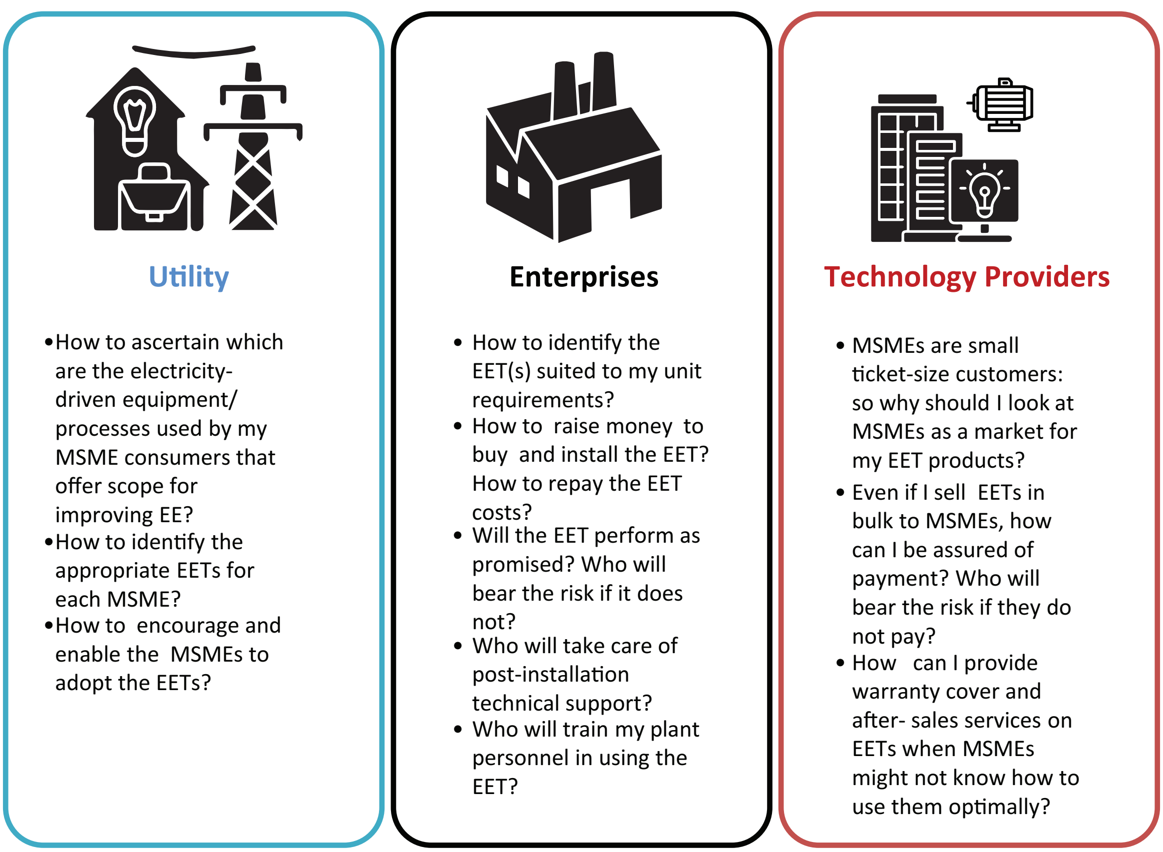


Figure 51: Key concerns of the three primary stakeholders

6.2.1 Load Research

The first and most important step in implementing the DSM program is to carry out a comprehensive 'load research' study of the daily and seasonal variations of electricity demands in the MSME cluster(s) targeted, the characteristics of the MSMEs in different sub-sectors, and their electricity usage patterns. The load research study may be commissioned directly by the utility (under the program 'Capacity building of DISCOMs' of Bureau of Energy Efficiency, Ministry of Power), and conducted by qualified professionals/ energy auditors. The results of the study will enable the utility to:

- Assess the overall potential demand for the EET(s) among the MSMEs, as well as the density and distribution of the demand for each EET
- Invite applications from the MSMEs for installing the EETs
- Identify suitable EET providers, and invite them to quote prices for bulk-supply of their EET(s) to meet the aggregated demands[25]
- Identify a suitable ESCO if required to implement the DSM program (as in Model A)

6.2.2 Model A: Vendor-based ESCO

6.2.2.1 Suitability

This DSM model is recommended for implementation of energy efficient technologies such as premium efficiency motors and EE air compressors. MSMEs require external expertise/ technical support during installation of these technologies. These EETs need to be backed by technical support services (serving infrastructure, maintenance, etc.) during and after their warranty periods. Hence, the involvement of an ESCO as a separate business entity, which can provide the required technical support to MSMEs during and post-installation, is preferable for the roll-out of the model (figure 52).

6.2.2.2 Implementation steps

- The utility receives and approves the MSME's application for an EET, and then requests both ESCO and EET provider to arrange for delivery of the EET to the MSME.[26]
- ESCO makes payment to the EET provider (either up-front or in instalments via performance guarantee), and ensures that the EET is delivered at the MSME's premises.[27]
- ESCO may arrange for installation and commissioning of the EET, if the MSME so requests [Optional]
- Starting from the month following delivery of the EET, the utility starts recovering the 'landed cost' of EET (i.e., EET cost + ESCO's profit + utility's own project management charges) from the MSME, through EMIs that form part of each monthly electricity bill. The number of EMIs will depend on the simple payback period calculated for the EET, with a maximum of 12 EMIs allowable.

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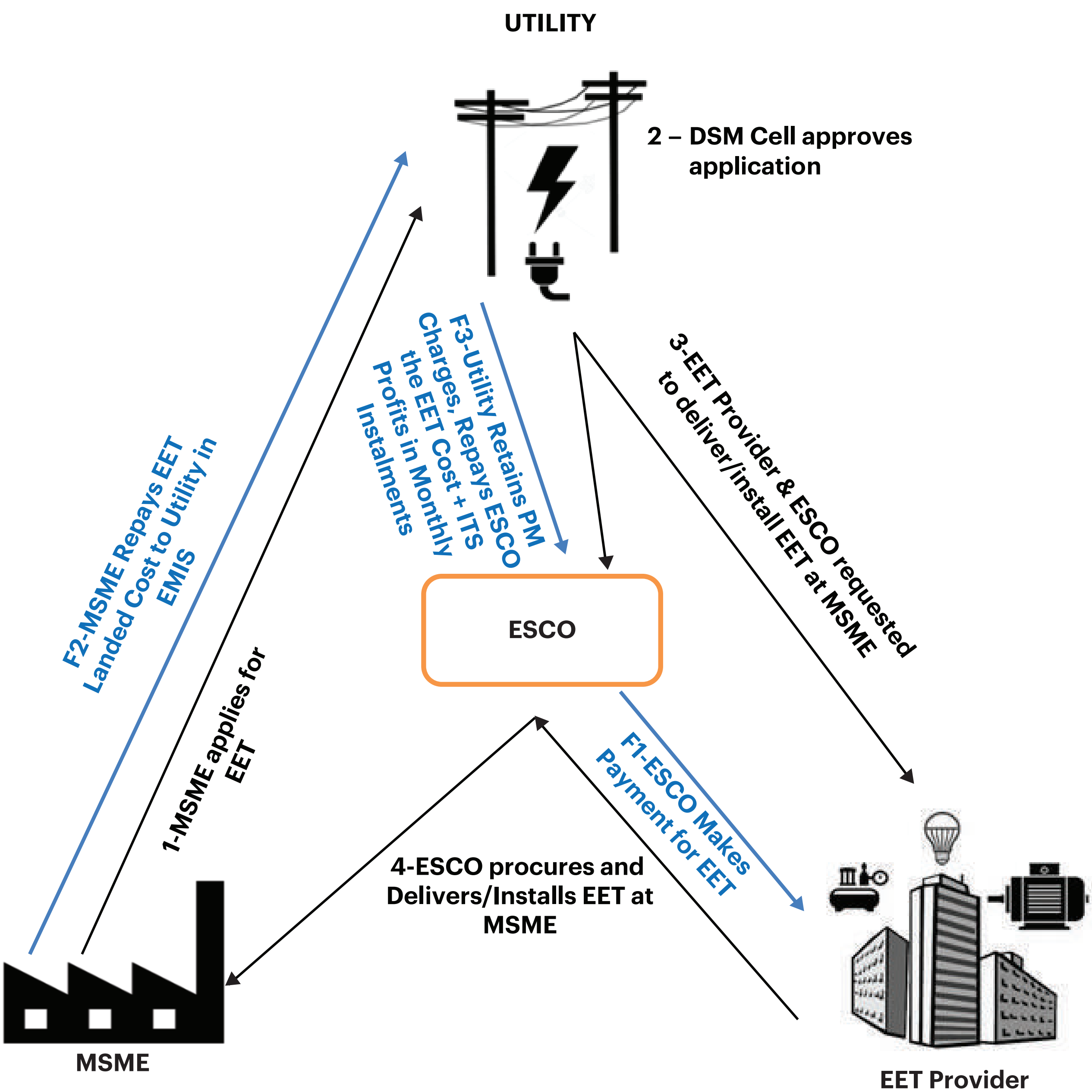
[25] In order to ensure that only the best-quality technologies are procured and promoted under the DSM program, EET providers may be pre-qualified before bids are invited from them under the L1 tendering process.

[26] Each EET application may carry a simple number code, and the same number code may be quoted in all subsequent documentation (EET provider's invoice and delivery order, monthly electricity bill, ESCO fee payment, etc.) to enable accurate and seamless tracking of each transaction till its completion.

[27] In case the ESCO avails of a commercial loan for its investment in the DSM program, the loan may be insured against investment risk under the Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE)



Note: Blue arrows and text show finance flows

Figure 52: Model A: Vendor-based ESCO model

- Out of the EMI recoveries, the utility will retain its own project management charges and pass on the balance to the ESCO on monthly basis. Thus, the ESCO receives a monthly return from the utility, comprising part-repayment of EET cost + ESCO profit.

UJALA

UJALA (Unnat Jyoti by Affordable LEDs for All) is a scheme to promote the large-scale adoption of energy efficient LED lamps across India. UJALA was launched in 2015 by Energy Efficiency Services Ltd (EESL), "Super-Energy Services Company (ESCO)" under the Ministry of Power, Government of India.

Initially targeting the domestic sector, UJALA adopts a strategy of demand aggregation, mass awareness and bulk procurement, through which LEDs are procured at low prices and distributed to consumers free of upfront charges. The costs of the LEDs are then recovered from the consumers in easy instalments through their monthly electricity bills. As of February 2020, UJALA has already distributed over 361 million LED lamps across India, and is saving nearly 47 billion kWh of electricity annually. [http://ujala.gov.in/] UJALA has also resulted in a sharp decrease in market prices of LEDs.

6.2.2.3 Key features

- Open to all MSME consumers
- All empanelled ESCOs offering the identified EETs can participate
- No initial investment required by MSME on EET
- EMI period: 12 months maximum or based on payback period

6.2.3 Model B: Utility-based ESCO

6.2.3.1 Suitability

This model is recommended for EETs like LED lamps and BLDC ceiling fans[28], where the installation and use of the EET is simple, easy, and the technologies require minimal technical support after installation. Hence, this model can be rolled-out by the utility directly, without involving an ESCO as a separate business entity; instead, the EET provider is retained (through contract clause) to provide technical services as may be required during the warranty period (Figure 53).

6.2.3.2 Key steps

- The utility arranges for bulk procurement of the EET against payment via performance guarantee.
- Upon receipt of the MSME's application for the EET, the utility delivers the EET to the MSME.
- Starting from the month following delivery of the EET, the utility starts recovering the 'landed cost' of EET (i.e., EET cost + utility's own project management charges including return on investment) from the MSME, through EMIs that form part of each monthly electricity bill. The number of EMIs will depend on the simple payback period calculated for the EET, with a maximum of 12 EMIs allowable.

[28] TATA Power-DDL is already promoting the adoption of LEDs and BLDC fans among its industrial and commercial consumers, with procurement of these EETs via EESL's UJALA scheme.

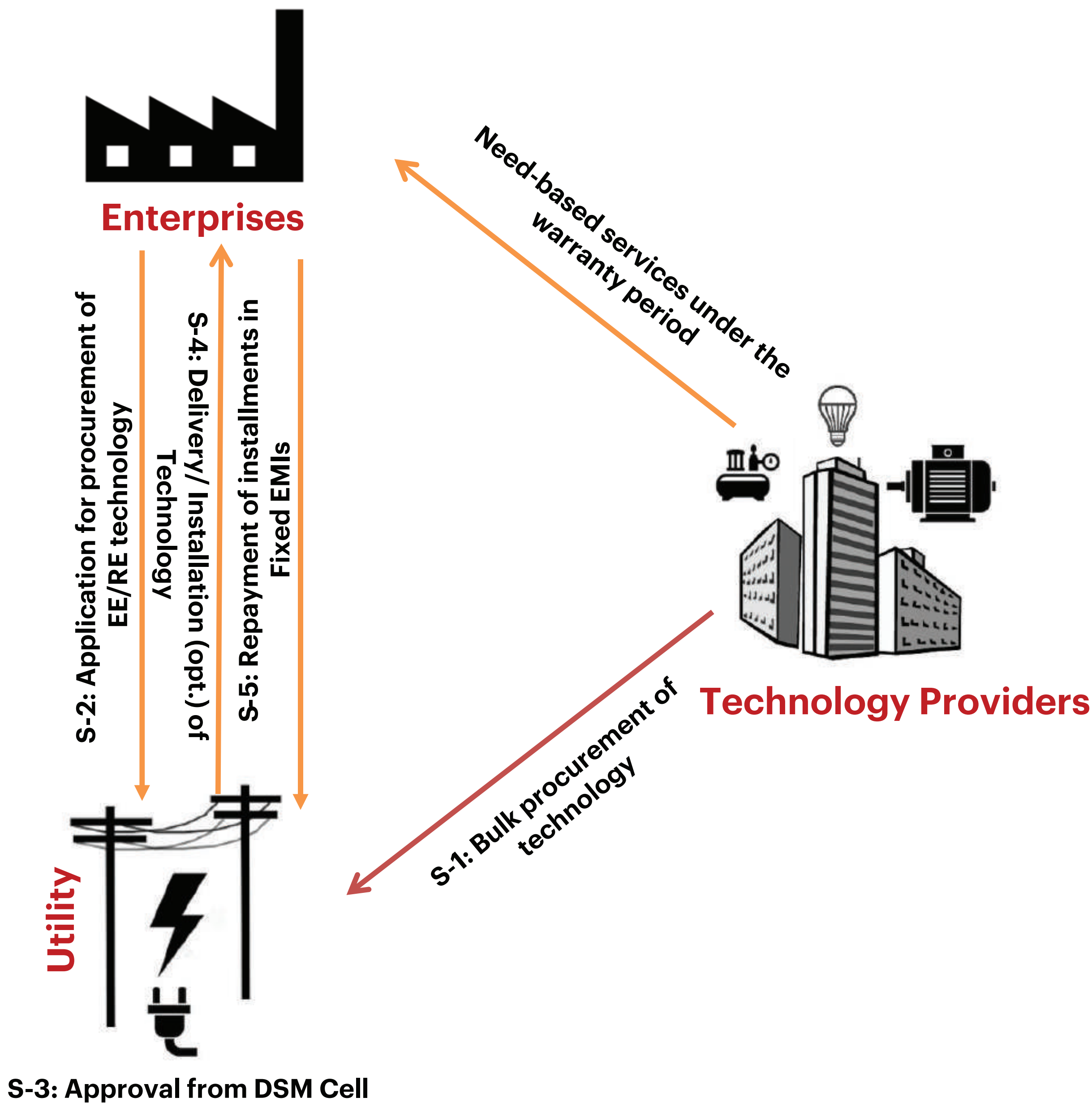


Figure 53: Model B: Utility-based ESCO model

6.2.3.3 Involvement of an expert agency

Having in place a business model alone is generally not sufficient to attract participation, especially among industrial and commercial consumers. A crucial role can be played by an expert agency, whose services will include the identification of the saving potential, as well as interactions with customers and vendors. Measuring and verifying savings is also essential for the utility to demonstrate the results of the program. Alternatively, the utility may need to invest in the development of energy service providers at the local level. The local energy service contractors could play a role in guaranteeing EE equipment performance, and in monitoring and verifying energy cost savings.

These additional services can aid in marketing the program and in making it more attractive to customers.

TATA Power-DDL and UJALA

Since 2017, TATA Power-DDL in collaboration with EESL has extended the UJALA scheme to its industrial and commercial consumers as well. Under the scheme, every consumer of TATA Power-DDL is eligible to get LED bulbs, LED tube lights and BEE 5-star rated ceiling fans at special subsidized prices to be paid up front, and with no limit to the quantity of products purchased. EESL is solely responsible for the performance and warranty service of the products.

6.3 Case Study of Business Models

Case-studies of the two business models are provided below.

6.3.1 Business Model A: Vendor-based ESCO

This business model should cover the cost of the EETs as well as profit of the ESCO/vendor and project management fee of the utility. A case study of financing a premium efficiency class (IE3) motor of capacity of 15 kW under the model is given in Table 24.

Table 24: Case study of a vendor-based ESCO business model

Parameters	Unit	Value
Name of EE technology	-	IE3 Motor
Investment	₹	34,515
Profit of ESCO (@9.5%)	₹	3,279
PMC charges of utility (@3.5%)	₹	1,323
Landed cost to unit	₹	39,117
Annual cost saving (@ 18 hrs/day, 300 days)	₹/Year	28,750
EMI /Monthly return (@12 EMIs)	₹/Month	3,260
RIM	Paisa/kWh	0.0003

In the model, the total landed cost of EET to the units has been increased by approximately 13"% to include the profit of the ESCO and fee of the utility which will be recovered from the end-user. The ratepayer impact assessment (RIM) test was found to be positive as the consumer category (industry) is cross-subsidizing the electricity for other consumer categories (domestic and agriculture) in India.

6.3.2 Business model B: Utility-based ESCO

This business model should cover the cost of the EET as well as the project management fee of the utility. A case study for financing a premium efficiency class (IE3) motor of capacity of 15 kW under the model is given in Table 25.

Table 25: Case-study of a utility-based ESCO business model

Parameters	Unit	Value
Name of technology	-	IE3 Motor
Investment	₹	34,515
PMC charges of Utility (@3.5%)	₹	1,208
Landed cost to unit	₹	35,723
Annual Cost saving (@ 18 hrs/day, 300 days)	₹/Year	28,750
EMI /Monthly return (@12 EMIs)	₹/Month	2,977
RIM	Paisa/kWh	0.0003

The total landed cost of EET has been increased by approximately 3.5"% as the fee for the utility The EMI for the selected EET is reduced by 8.5% under the utility-based ESCO model (compared to the vendor-based ESCO model), making it attractive for the end-users.

6.4 Prerequisites and Imperatives

There are several prerequisites before the roll-out of the proposed business models. These are detailed in Table 26.

Table 26: Prerequisites to the roll-out of vendor/utility-based ESCO business models

S. No.	Regulatory side	Operation side
1	➢ Development of project document » Technologies identified » Targeted consumers » Duration of project » RIM Test	➢ Development of project document ➢ Energy saving model finalization (deemed saving model)
2	➢ Approval of project management fee to be charged by the utility under O&M head	➢ Selection of technologies in close consultation with local industry associations, consumer representatives
3	➢ M&V protocol and suitable agency for assessment of energy saving achieved, consumer benefited, impact on overall demand profile, etc.	➢ Consultation with ESCOs and technology providers on cost, delivery, post-sales services, etc.
4	➢ Post-implementation reporting	➢ Financial assessment on return on investment (in case of utility- based model)

Accurate estimation of the energy saving achieved under the model project is one of the major barriers. Most ESCO-based models adopt the deemed saving model, like the UJALA scheme of EESL. The imperatives in rolling out the ESCO model include the following:

- **Variable operating hours –** End-use operating hours of the appliance/EET may vary in different units affecting actual energy savings.
- **Repayment period -** Most business models consider a repayment period of 12 months. In practice, however, the payback period for each consumer would be different. Hence, suitable assumptions on energy savings need to be taken into consideration for the project document.
- **Higher equipment cost –** The profit of ESCOs and project management fee of the utility will increase the overall cost of the EET, and hence the customer may have to pay almost the market price of the technology.

7. STRATEGIES TO SCALE UP

Through the Energy Conservation Act, 2001, Electricity Act, 2003 and National Electricity Policy, Demand Side Management (DSM) has been accorded priority. Further, the National Electricity Policy has also emphasized on the need for differential pricing for load shifting. In addition to these efforts, various state electricity regulatory commissions have also notified DSM regulations for their distribution licensees. In 2015, Karnataka Electricity Regulatory Commission (KERC) notified DSM regulations with an overall objective of improving energy efficiency in the state. Despite all these efforts, DSM has not been able to take off in India at a large scale. Though some efforts have been made in silos in some states, enforcement of DSM regulations continues to be limited. The responsibility for on-ground implementation continues to rest with the distribution companies (DISCOMS) who have not been able to undertake large-scale programs due to several technical, institutional and financial barriers. DISCOMs are ideally positioned to develop and implement energy efficiency improvements using the DSM tool in the industrial consumer category within their licensee areas.

The study has established that demand aggregation based formulation of DSM programs provide an exciting, hitherto largely-unexplored avenue through which electricity utilities as well as their MSME consumers can derive financial and other benefits. It describes how utilities can become demand aggregators for EETs and implement ESCO-based business models for DSM, jointly with EET vendors, to remove the most significant barrier to the adoption of EETs by MSMEs—namely, the relatively high costs of initial investments. Under these ESCO-based business models, the utility recovers the costs of the EET from the MSME via the monthly electricity bill. The utility will have a 'cut' or mark-up on the capital investment—ensuring that there is a return on investment (ROI) for the utility as well.

There is also huge potential for utilities to replicate these ESCO-based business models for DSM in MSME clusters across the country. Scaling up of DSM nationwide will contribute significantly to the effective implementation and outcomes of the National Mission for Enhanced Energy Efficiency. It will also add value to India's emission reduction commitments under the Paris Agreement, through the avoided addition of fossil fuel-based generation capacity.

However, the first and most important barrier in the replication of similar DSM projects in other utilities is 'information'. Most of the utilities lack information about the load and consumption patterns of industrial consumers, which hinders development of comprehensive DSM programs. Additionally, very few small and medium businesses have carried out energy audits to save energy costs. The level of interventions, EETs, and their demand could be gauged by conducting sample energy audits in energy-intensive MSME units. The energy audit studies for DSM programs need to take into consideration the following factors:

- Cost to customers
- Value of avoided losses resulting from improved efficiency and system reliability
- Potential losses in production during implementation.

The scaling-up of ESCO-based DSM programs could be undertaken in two stages. In the initial stage, utilities may implement DSM in a few select circles among their MSME consumers, to demonstrate the benefits that various stakeholders obtain from the ESCO-based DSM model(s). In the next stage, DSM implementations may be extended across the entire licensee area of the DISCOM through engagement with public and private institutions and organizations that can support as well as derive benefits from the DSM scaling-up initiative (Ministry of Power, Ministry of MSME, BEE, CERC, EESL, state electricity regulatory authorities, SDAs, industry federations and associations, EE equipment manufacturers, EE service providers, financial institutions, energy auditors and others).

The utilities and their partners may also take advantage of the knowledge resources and opportunities provided by the various national-level initiatives by government agencies to bring about EE improvements among MSMEs.

7.1 Approach

An integrated well-targeted approach needs to be adopted by utilities for DSM programs. The programs should be designed for specific market segments and customized for removing specific barriers. Distribution utilities could adopt the following approach in either energy-intensive MSME units or at the cluster level, to initiate and take forward the DSM scaling-up process.

- Commissioning demand aggregation based DSM programs by energy audit agencies in select circle(s) with prior approval of the regulator, either on their own or with support from government and other donor agencies.
- Consultations with EE equipment manufacturers or technology providers and their dealers, ESCOs and local service providers to gauge their willing to participate in the DSM initiative
- Outlining customized ESCO-based business model as per consumer needs, including the roles and responsibilities of key stakeholders.
- Generating awareness about the EETs, their benefits, available financing model, and other benefits through consumer meets/cluster-level workshops with stakeholders, documenting and disseminating success stories and through one-on-one meetings with consumers. Two awareness events, in Delhi and Mumbai were organised under the project. The summaries of the events are provided in Annex 11 and 12.
- Providing technical assistance to interested MSME units in customization or selection of new technologies.
- Documentation of the impacts in terms of electricity savings, demand reduction, and other benefits (O&M, unscheduled power cut, etc.).

7.2 Key Actors

The roles and activities of some of the key entities who could support the utilities in scaling up DSM programs are summarized below.

A 'deep dive' approach focuses on promoting EE technologies that are commercially available but not yet widely adopted by consumers

7.2.1 ESCOs

In order to pave the way for implementing and scaling up DSM for common EETs like motors, ceiling fans, lights, air compressors, etc., there is a need to identify and develop suitable cluster-level ESCOs. The ESCOs could typically be business entities having good rapport and strong linkages with the local industries, and the acumen and wherewithal to provide the MSMEs with turnkey services for replacing their conventional low-efficiency technologies with EETs on a large scale. For instance, the ESCO could be the local dealer of the EE equipment manufacturer; or a credible local services provider. Some resources may be needed to identify and develop such ESCOs, especially in the initial stages.

The ESCOs could take on the responsibilities for:

- Contract finalization
- Initial investment on EETs (only in Model A: vendor-based ESCO)
- Technology installation/implementation
- Performance monitoring
- Training of plant personnel
- Providing/arranging for technical support services during warranty period
- Follow-up on recoveries from individual MSMEs if needed.

7.2.2 Industry Associations

Industry associations could play a critical role in the formulation, implementation and scaling up of the DSM initiatives, including:

- Awareness generation activities
- Recommending potential ESCOs
- Serving as a bridge between the ESCO and consumer.
- Encouraging MSME units to participate in the program

7.2.3 State Designated Agencies (SDAs)

- Creating awareness about the DSM opportunities across the state
- Assisting in availing of financial incentives from the government.

7.2.4 Banks/Financial Institutions

- Developing special packages for providing financial assistance to ESCOs with backing from government/donor-funded schemes

7.2.5 Energy Audit Agency

- Developing DSM programs to achieve high energy savings
- Conducting 'deep dive' interventions in energy-intensive MSME clusters
- Undertaking unit-specific feasibility studies
- Facilitating pilot EE projects
- Supporting M&V of energy savings

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Annexures

Annex 1: Engineering

Most of the engineering units within the licensee area of Tata Power DDL are concentrated in the industrial areas of Badli (Phase – 1& 2), Naraina, Kirti Nagar and Najafgarh of West and North Delhi. These locations are shown in Figure 1.1.

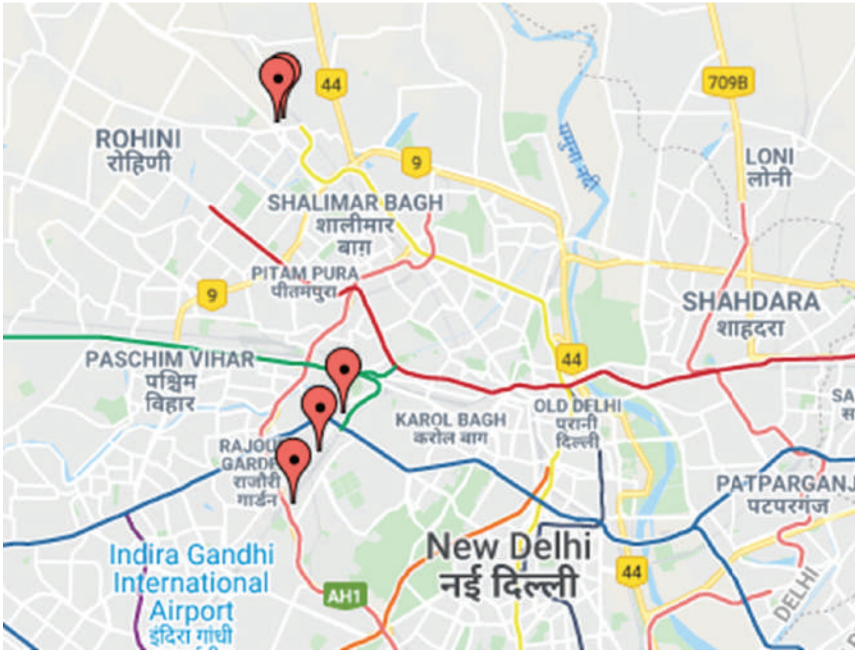


Figure 1.1: Clusters of engineering industries in Delhi

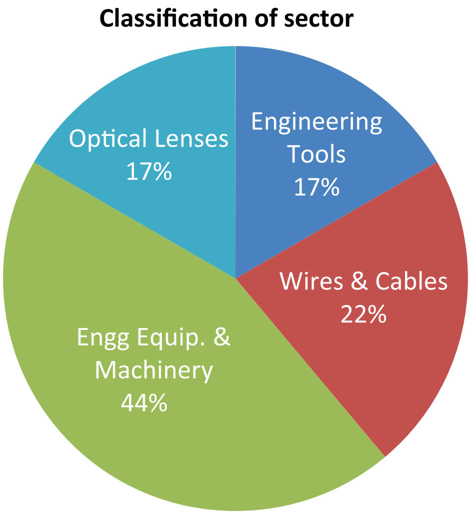


Figure 1.2: Major engineering sub-sectors

These engineering units are involved in the manufacture of various tools and components used by industries. Some of the industries which are catered to by the sector include engineering equipment and machinery (heavy & light engineering), wires & cables, engineering tools, optical lenses, etc. The engineering units can be categorised into different sub-sectors as depicted in Figure 1.2. Some of the leading engineering equipment manufacturing units in the distribution licensee area include Continental Device, Kamal Industries, Chandra Electrical Industries, and Horizon Industrial Products.

1.1 Production Process

The installed capacity and production process of engineering units vary with the nature of the product. Often, there are variations in the process even within the same product category.

The production process in the engineering sector is intermittent. Items are produced in batches; the products are shaped by forging, moulding, etc. and machined. Milling, cutting, drilling, threading are some of the common machining operations. Photographs of a sheet metal cutting machine and a hydraulic milling machine is shown in Figure 1.3 and 1.4, respectively.

Figure 1.3: Sheet metal cutting machine

Figure 1.4: Hydraulic milling machine

Consumer products like ophthalmic eyeglasses are obtained in a semi-finished stage and then finished as per customer specifications to obtain the final product.

The generic manufacturing process adopted by some of the engineering sub-sectors is described in the following sections.

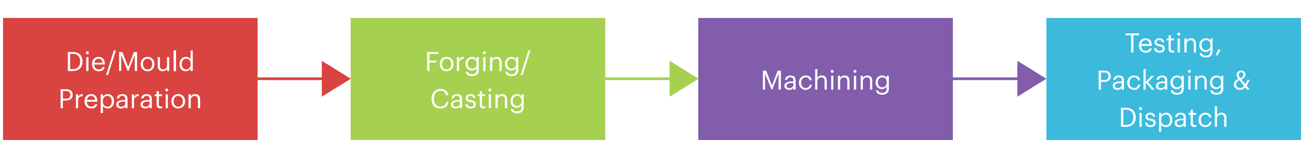


Figure 1.5: Typical production process of engineering equipment

1.1.1 Engineering equipment

The typical production process of an engineering equipment manufacturing unit is shown in Figure 1.5.

Die/mould preparation: The die block required for the forging process or the mould required for the casting process are first prepared as per the design specifications of the end product.

Forging/casting: Forging involves power pressing/hammering the hot metal sheet/ block to give it the shape of the die while casting involves melting of metal scrap and pouring it into moulds. Variations of these processes are used based on the nature of the final product.

Machining: The forged/casted products are then machined. Operations like threading, cutting, drilling, grinding, etc. are carried out as per the specifications of the product.

Testing, packaging, and dispatch: The final products are tested for quality and design conformations either in-house or by an external laboratory. After passing the tests, the products are packed and readied for despatch.

1.1.2 Wire drawing

Wire drawing or metal forming is the process used to reduce the cross-section and increase the length of the product. This process is associated with the tensile force which distinguishes it from other metal forming processes like extrusion, forging, etc. In this process, a larger cross-section feedstock is forced to pass through a die which has a smaller opening compared to the cross-section of the work piece. This process is used for making wires, rods, tubes, etc.

A typical process flow of a wire drawing unit is showing in Figure 1.7.

Figure 1.6: Wire drawing machine

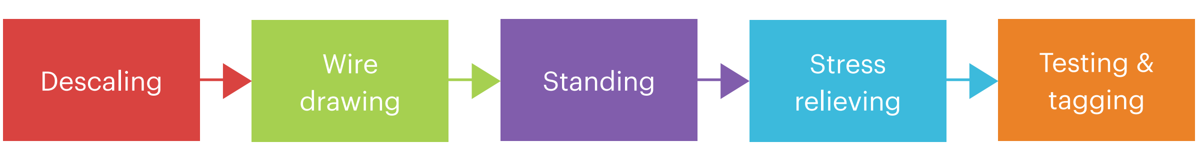


Figure 1.7: Process flow in wire drawing

Descaling: The raw material is a wire rod. The raw material is first descaled to remove the top oxide layer.

Wire drawing: The wire rod is drawn into different sizes as per the end-use requirements or specifications of the buyer. In this hot extrusion process, the wire rod is plastically deformed causing elongation and a decrease in cross-section area.

Standing: After achieving the desired shape and size, the wire rod is kept in the storage yard.

Stress-relieving: The elongated wire is heat-treated to relieve the stresses caused due to elongation.

Testing and tagging: After the stress-relieving process, the wire rod is tested to check whether it has attained the desired strength. After testing, the product is tagged and made ready for dispatch.

1.2 Electricity and Demand Profile

In engineering industries, electric motors associated with different processes like presses, extruders, rollers, coilers and so on account for the largest share of its electricity consumption (83%), followed by air compressors (14%), lighting system (2%) and space cooling (1%). Most of the engineering units operate in single or two shifts. There is large variation in the electrical load from 30 to 90% of the contract demand on a daily basis. The peak load is reached during morning hours. The typical loading pattern of a unit operating in single shift shows a sharp increase in the load at the start of the shift and a sharp decline in the evening. Electrical demand and end-use consumption pattern in a typical unit is shown in Figure 1.8.

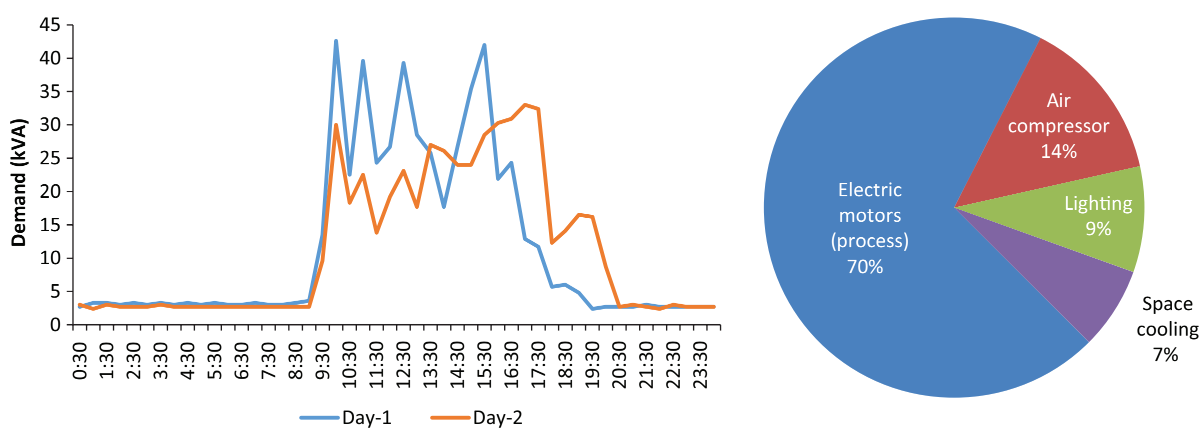


Figure 1.8: Electricity demand variation and end-use pattern in an engineering unit

The contract demand in engineering units varies widely from 37 kVA to 400 kVA. The overage load factor during a year varied in the range of 6–62%. The average demand utilization factor was found to be 68%. The demand utilization and load factors of selected engineering units are shown in Figure 1.9.

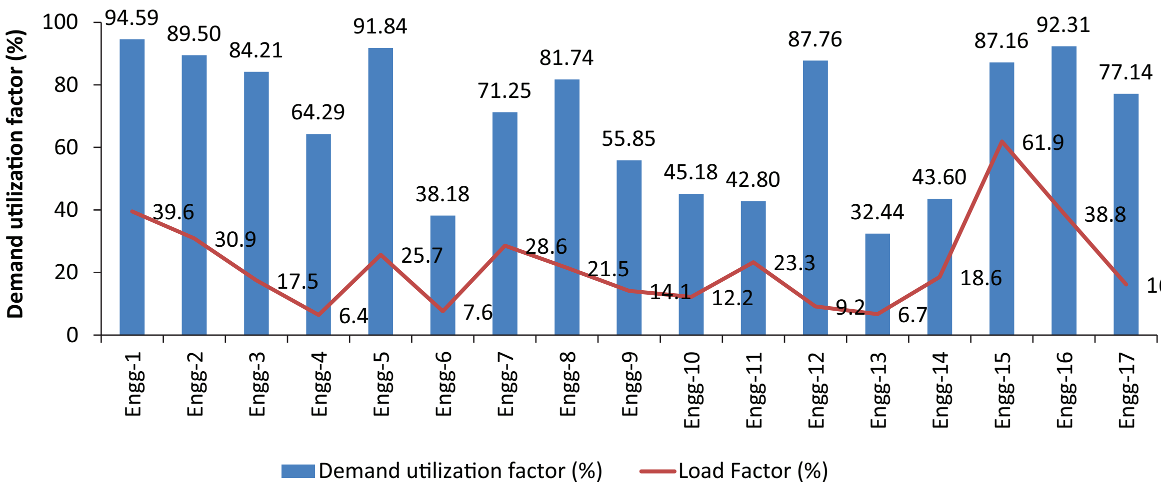


Figure 1.9: Demand utilization factor and load factor of different engineering industries

The poor load factor pattern of electricity consumption indicates that almost half of the engineering industries have double shift operations.

1.3 Technologies Employed

Some of the major areas/equipment used by these industries are detailed below:

Forging/casting: Forging and casting are important manufacturing processes among engineering units. The power press used in forging and the melting furnace used in casting are the major consumers of electricity in these units. The metal sheet/block is power pressed under the die block to make forged products. The scrap metal is charged into a melting furnace and the melt is poured into moulds to make casted products. The electric motors associated with press and cooling water pumps are standard efficiency class and often rewound multiple times.

Hot extrusion: The electric heaters used in hot extrusion process in wire drawing units consume large amounts of electrical energy. Most extruders use an on-off type electrical heating system. The surface insulation of the heaters is usually poor. The electric motors associated with the extruders are of standard efficiency class and have been rewound multiple times.

Utilities: Electric motors are widely used in utilities such as air compressors. The air compressors are usually continuously operating and consume large amounts of energy. Little attention is paid to optimise operating parameters such as temperature of intake air, generation pressure, capacity utilization, design of the distribution piping network etc. and save energy. Both reciprocating and rotary screw type air compressors are used. Most of the air compressors are fixed speed type. The air pressure required for most applications is below 6.5 kg/cm^2 (g). The use of conventional lamps such as CFLs, FTLs (T-8/T-12), incandescent bulbs and mercury vapour lamps is widespread. Relatively a few units have adopted LED lighting.

The average power factor in these units varies from 0.95 to unity. Most units have fixed type capacitor banks while some have automatic power factor correction system. The power factor correction systems are often not optimised resulting in a power factor between 0.95-0.97 in most units.

1.4 DSM/EE Opportunities

The following energy efficient technologies can be adopted by the engineering industries.

Premium efficiency class electric motors

A majority of the motors in use are standard efficiency type motors. The ratings of these motors vary between 2.2 to 75 kW. Most of these motors were found to operate on low or partial loads. The power factor of the motors was found to be below 0.70. Multiple rewinding of motors is common. The efficiency of a motor drops between 1-5% after each rewinding. Substantial energy can be saved by replacing the under loaded and rewound motors with premium efficiency class (IE3) motors as given in Table 1.1.

Table 1.1: Energy saving opportunities in electric motors

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of under loaded motors with optimum capacity IE3 motors	Motor loading is between 40–65%	Recommended motor loading is between 65–95%	5–7%	< 2 years
Replacement of standard/rewound motors with IE3 motors	➢ Standard efficiency class motors ➢ Rewound multiple times	Premium efficiency class (IE3) motors (IS12615)	5–7%	< 2 years

Compressed air system

While the maximum air pressure requirement at the utilization end is 6.5 kg/cm^2(g), the generation pressure in the air compressors was found to be between 7.5–10 kg/cm^2(g). Also, the actual demand of compressed air is much below (50–60%) the rated capacity of the compressor. The specific power consumption (SPC) of the air compressors was found to be in the range of 0.19–0.25 kW/CFM which is very high. For large variations in the air demand, adoption of inverter type (variable frequency drive) air compressor with super premium efficiency (IE4) class motor is recommended. Adoption of these air compressors would reduce the SPC to between 0.15-0.16 kW/CFM, The DSM/EE opportunities are summarised in Table 1.2.

Use of LED lamps and lights

The share of electricity consumption in illumination system ranges between 1–2%. Replacement of the conventional lamps with energy efficient LED lights will not only reduce the lighting demand but also increase their operating life The DSM/EE opportunity is summarised in Table 1.3.

Table 1.2: Energy saving measures in compressed air system

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Optimum setting of compressed air generation pressure	➢ Set pressure: 7.5–10 kg/cm²(g) ➢ End user pressure requirements: 6.5 kg/cm²(g)	➢ Set pressure: 6–7 kg/cm²(g) ➢ End user pressure: 5.5 kg/cm²(g)	10–15%	No cost measure
Rotary screw type air compressors with IE4 efficiency class motor and VSD system	➢ Fixed speed, screw type air compressor ➢ Capacity utilization: 50–60% ➢ Unload period: 40–50% ➢ SPC: 0.19–0.25 kW/ CFM	➢ SPC: 0.15–0.16 kW/ CFM ➢ No unloading losses	15–17%	2–3 years
Replacement of tank-mounted reciprocating (5.5 – 18.5 kW) by rotary screw type air compressors	➢ SPC: 0.19–0.25 kW/ CFM ➢ On-OFF mode	➢ SPC: 0.16–0.18 kW/ CFM ➢ Variable speed mode (optional)	12–23%	2–3 years

Table 1.3: LED tube lights and bulbs

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of FLTs with LED tube lights	➢ Fluorescent tube lights (T-8/T-12) ➢ Capacity: 44–52 W	➢ LED tube lights ➢ Capacity: 18/20 W	55–60%	< 0.5 year
Replacement of incandescent bulbs with LED bulbs	➢ Incandescent light bulb ➢ Capacity: 60/100 W	➢ LED light bulbs ➢ Capacity: 7/9 W	80–85%	< 0.5 year
Replacement of MVL/ SVL with LED bay/flood light (shed light)	➢ MVL/SVL lamps ➢ Capacity: 75–250 W	➢ LED light ➢ Capacity: 35/125 W	55–60%	<1 year

Energy efficient BLDC fans

Most units are using conventional fans (wall mounted, pedestal and ceiling) for space cooling purposes. These fans are equipped with single phase induction motor of capacity between 65–90 W. These fans can be replaced with energy efficient BLDC fans which consume 28–35 W. The DSM/EE opportunity is summarised in Table 1.4.

Table 1.4: Energy efficient BLDC fans

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of conventional fans with BLDC fans	➢ Conventional induction motor type fans ➢ Capacity: 65–90 W	➢ Energy efficient BLDC fan ➢ Capacity: 28-35 W	55–60%	<1 year

1.5 Key Technologies and Energy Saving Potential

The key technologies which can be aggregated to promote DSM in engineering sector include the following:

- Premium efficiency class motors,
- Energy efficient air compressors
- Energy efficient LED lighting and
- BLDC fans

In addition to these technologies, unit-specific customized solutions like power factor correction system, VFD retrofitting in wire drawing machine, etc. can be implemented in these industrial units.

The assessments conducted under the project show that it is possible to save energy between 5.5–12.5% by implementation of the identified energy conservation measures in a typical engineering unit. The contribution of the individual EE technologies in the total energy saving is shown in Figure 1.10.

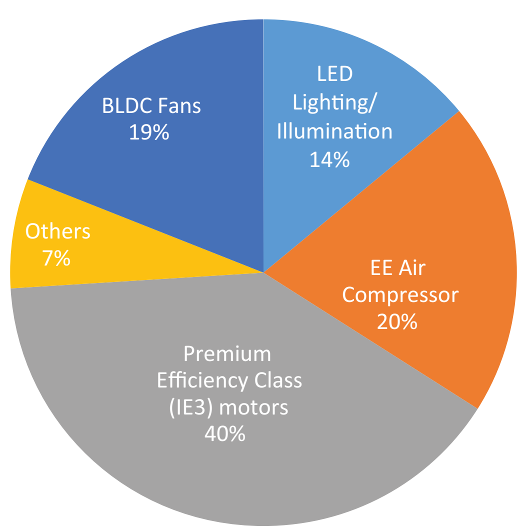


Figure 1.10: Contribution of different technologies in the energy savings

Annex 2: Food Processing

The major concentrations of food processing units under the license area of Tata Power–DDL are in the industrial areas of west and north Delhi. These locations are shown in figure 2.1. The food processing units are involved in the manufacture of a wide variety of bakery, snacks and nuts products. These units process various products as per the market demand and season. The units mainly cater to the local market and distribute their products directly or through bulk distributors. Some of the leading food processing units in the distribution licensee area include KBB Nuts, Gurukul Griha Udyog and Theobroma Foods

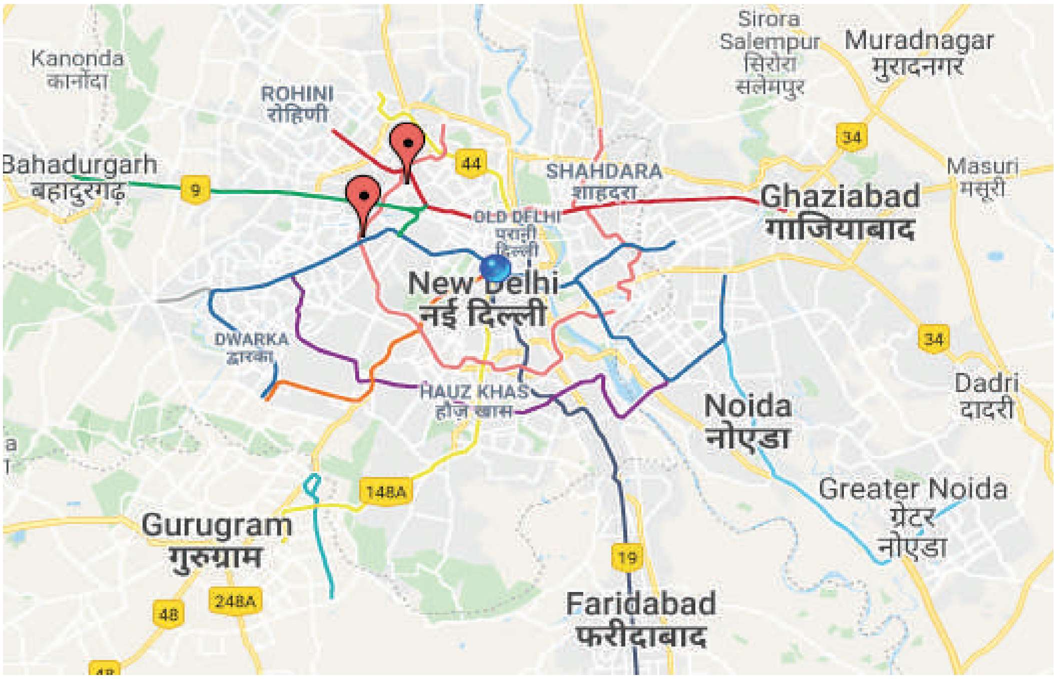


Figure 2.1: Clusters of food processing units in Delhi

2.1 Production Process

The major sections within a food processing unit are stores, raw material preparation, kitchen/baking/processing and packing & storage. A simplified process flow diagram of a food processing industry is shown in Figure 2.2.

Stores and raw material preparation: The unprocessed ingredients and raw materials are sorted and stored at controlled atmosphere (suitable temperature range) to maintain their desired life. The raw material stores are often equipped with a refrigeration system and fan coil units. Some of these units process a variety of foods as per their availability/demand throughout the year. Therefore the temperature of the storage area varies as per the raw material stored and the period. The ingredients are weighed and mixed as per the requirements of the final product.

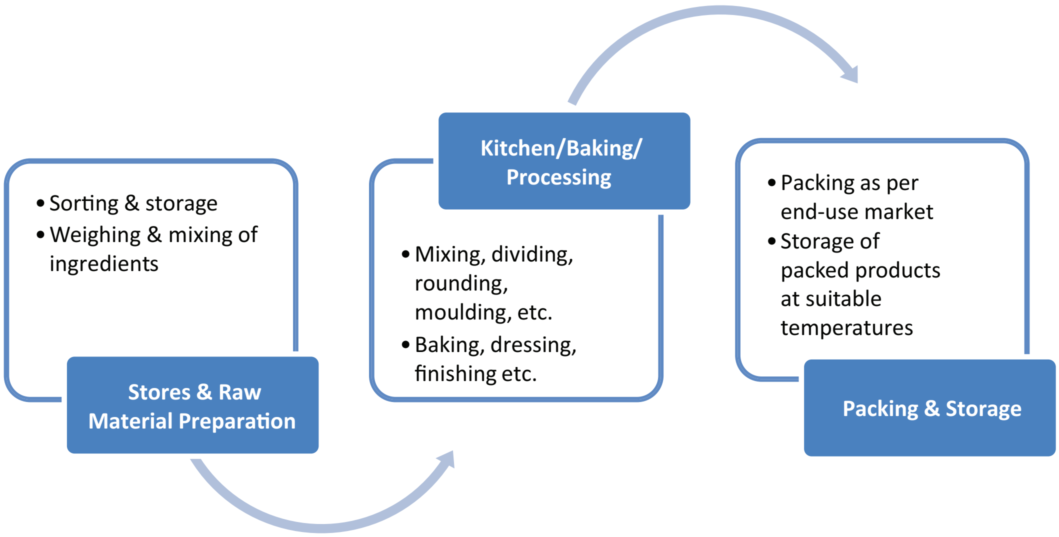


Figure 2.2: Typical processes in food processing industry

Kitchen/Baking/Processing: Various parameters need to be closely controlled in the main processing section or the kitchen. These include the raw material and processing temperatures, addition sequence of different ingredients, time of processing and so on. In bread production, yeast is used to ferment the sugars in the flour. The fermentation releases carbon dioxide gas. In order to maintain odour free environment, treated fresh air fan unit (see Figure 2.3) are installed in the fermentation section. In addition to the main kitchen appliances like oven, hot plate etc., associated utilities like refrigeration unit, fan unit, air curtain, etc. are the other energy consumers.

Figure 2.3: Treated fresh air fan unit

Packing and storage: As per the suitability of transportation, the processed food is packed to maintain freshness and hygiene. The final product is inspected and stored in a controlled atmosphere at suitable temperatures. Some storage facilities are equipped with a refrigeration system and fan coil units.

2.2 Electricity and Demand Profile

The major energy consumers in food processing units are the process refrigeration and heating, ventilation and air conditioning (HVAC) system (i.e. chillers, cooling towers, pumps, air handling units, etc.), kitchen/processing equipment and associated utilities, lighting and space cooling. Section-wise share of electricity consumption in a typical bakery is shown in Figure 2.4.

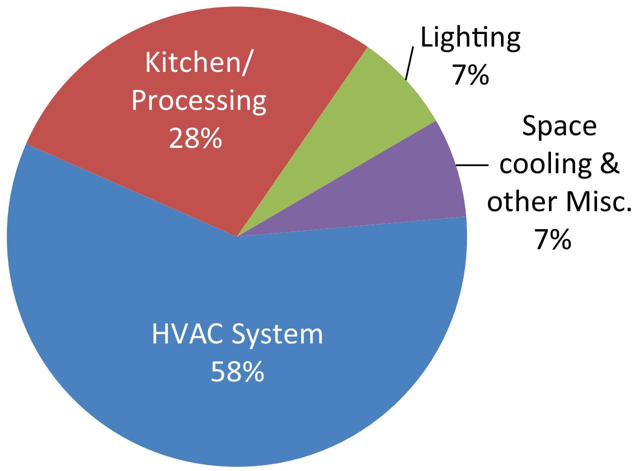


Figure 2.4: Section-wise electricity consumption in a bakery

Most of the food processing units operate in three shifts. The refrigeration and air-conditioning system, which accounts for the maximum load, operates irrespective of the operation of the kitchen. A typical load profile during weekdays and weekend of a food processing unit is given in Figure 2.5.

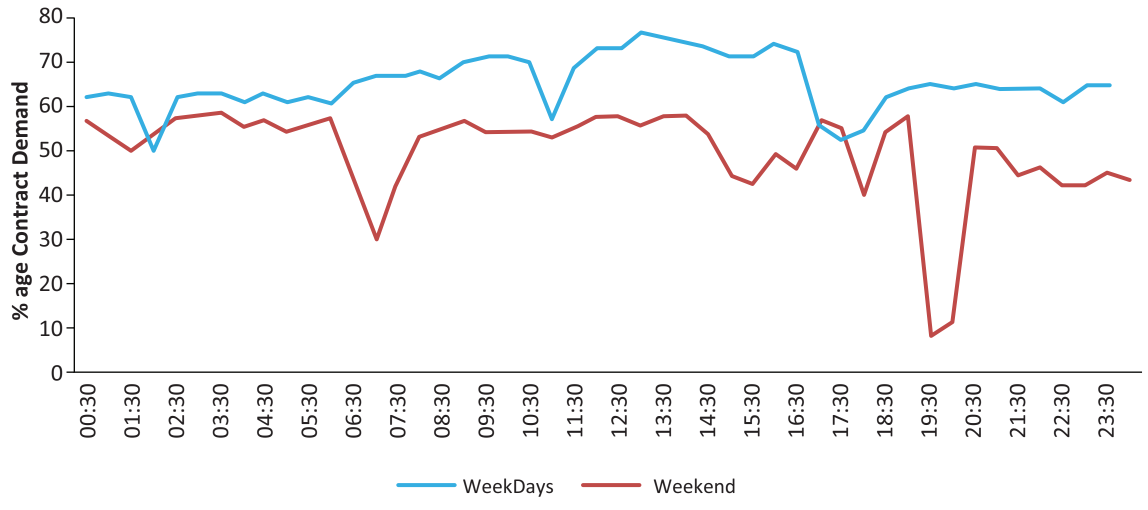


Figure 2.5: Typical load profile of a food processing unit

The contact demand varies between 125 kVA to 800 kVA. The average demand utilization is 72%. The demand utilization does not vary since the production remains almost constant. The load factor ranges between 10–50%. The variations in the demand utilization and load factors of a few food processing units are shown in Figure 2.6.

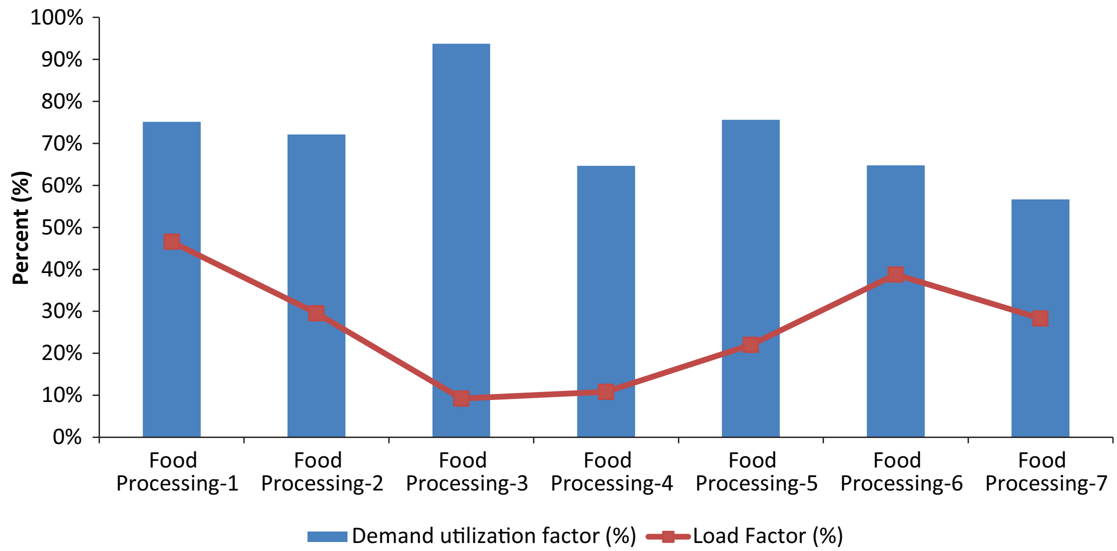


Figure 2.6: Demand utilization and load factors of food processing units

The average power factor in most units varies between 0.90 to unity. The use of automatic power factor correction systems and fixed capacitor banks at the main incomer and load-end for power factor correction is common.

2.3 Technologies Employed

Some of the major energy consuming equipment used in food processing are described below.

Process refrigration and air conditioing system: The refrigeration and air conditioning system consists of refrigeration compressors, air cooled condensers or cooling towers, and chilled water circulation pump. Electric motors are used with the water pumps and air circulation fans.

Most of the units use screw or scroll type compressors working on R134a and R404A refrigerant gas. Most systems are under loaded and controlled manually.

Photographs of some systems are shown in Figure 2.7.

Figure 2.7: Refrigeration and air conditioning equipment

Lighting/illumination system: The lighting in process areas is usually a mix of LED bulbs (7-9 W) and CFLs (8-36 W). The utility, storage and other common facilities are fitted with FLTs (T-8/T-12) as shown in figure 2.8. Very few units were aware about LED tube lights and its benefits. Therefore, adoption of LED tube lights remains low.

Figure 2.8: FLT lighting/illumination system

2.4 DSM/EE Opportunities

Common energy efficient technologies which can be adopted by the food processing units are discussed below.

Premium efficiency class electric motors

Most of the electric motors used in fan/blower units (i.e. AHUs, treated fresh air, air curtain, etc.) and pumps (condenser water and chilled water) are standard efficiency class. Use of rewound motors is common. The units do not maintain records of the rewinding history of the motors. The energy saving potential of replacing the standard/rewound motors with premium efficiency class (IE3) motors is summarized in Table 2.1.

Table 2.1: Energy saving opportunities in electric motors

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of standard/rewound motors with IE3 motors	➢ Standard efficiency class motors ➢ Multiple rewound motors	➢ Premium efficiency class (IE3) motors ➢ (IS12615)	5-7%	< 2 years

Use of LED illumination system

The illumination system accounts for about 7% of the total electrical load of these plants. Apart from higher electricity consumption, the heat generated by conventional lighting systems puts additional load on the air-conditioning system. Potential for energy savings by adopting energy-efficient LED lighting systems is summarised in Table 2.2.

Table 2.2: LED tube lights & bulbs

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of FLTs with LED tube lights	➢ Fluorescent tube lights ➢ Capacity: 44-52 W	➢ LED tube lights ➢ Capacity: 18/20 W	55-60%	< 0.5 year
Replacement of incandescent bulbs with LED bulbs	➢ Incandescent light bulb ➢ Capacity: 60/100 W	➢ LED light bulbs ➢ Capacity: 7/9 W	80-85%	< 0.5 year

2.5 Key Technologies and Energy Saving Potential

The key technologies which can be aggregated to promote DSM in this sector include the following:

(i) Premium efficiency class (IE3) motors (ii) Energy efficient LED lighting.

Based on the assessment studies, an overall electricity saving potential between 4.5-15% is estimated in the food processing sector.

Annex 3: Cold Storage

The cold storage units within the licensee area of Tata Power DDL are concentrated around Azadpur wholesale fruits and vegetables market (Mandi) and the industrial areas around Lawrence Road in West Delhi. These locations are shown in Figure 3.1.

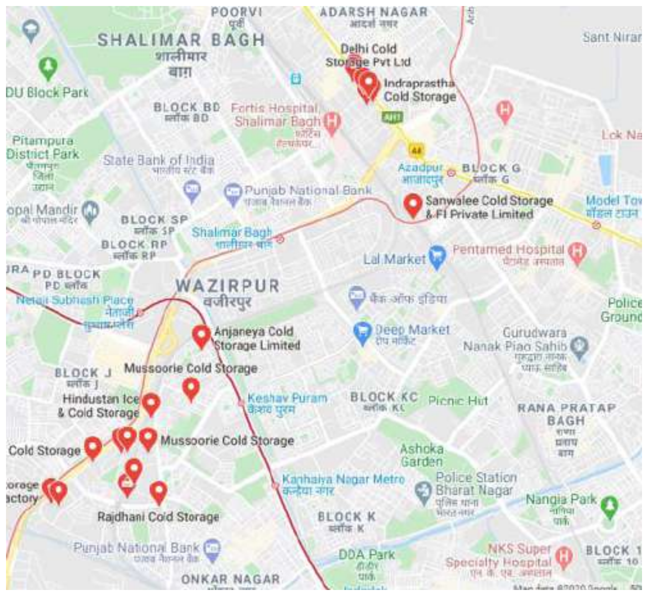


Figure 3.1: Cold storage clusters in Delhi

These facilities usually store fresh fruits, vegetables, and other horticultural products. The cold storage units came up in these areas due their proximity to the agricultural states of Haryana and Punjab and good connectivity by both road and rail modes of transport. Most of these cold storages have availed the government subsidy for development of cold storage and warehouse facilities. Some of the leading cold storages include Delhi Cold Storage, Indraprastha Ice and Cold Storage and Gulmarg Ice and Cold Storage.

3.1 Cold Storage Process

The linkage between farms, cold storage facility, and market is shown in Figure 3.2.

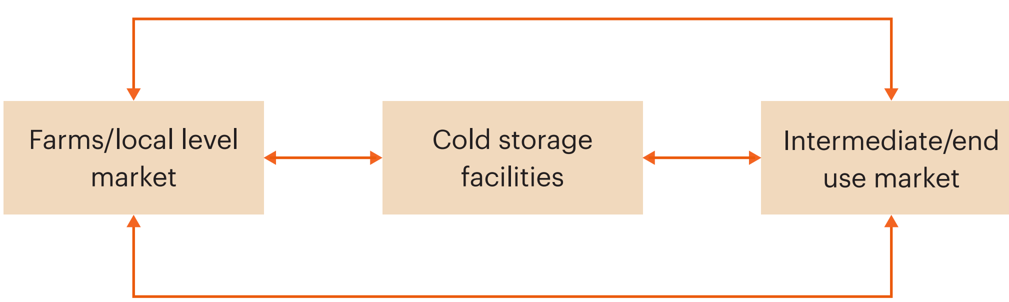


Figure 3.2: Forward and backward linkages of cold storage facilities

The storage process adopted by the cold storage facilities are described below.

3.1.1 Pre-cooling

Pre-cooling is the first step in the temperature management of fruits and vegetables after harvesting. Pre-cooling plays an important role in prolonging the shelf life of the produce by removing heat and reducing metabolic activities. There are multiple methods for rapid removal of heat from the produce. The cooling method is largely dependent on the perishability of the produce and the refrigeration equipment available at the facility. Some of the common processes used for pre-cooling of fruits and vegetables in cold storages include the following:

- Hydro-cooling
- Forced air cooling
- Evaporative room cooling
- Package ice cooling

3.1.2 Storage

Most of the cold storages are of multi-commodity type. A cold storage storing apples is shown in Figure 3.3.

Figure 3.3: Apples stored in cold storage

For long-term storage of maintenance of desired conditions, such as temperature, humidity, carbon dioxide (CO_2), and air circulation rate are critical. These parameters are discussed below.

Temperature and humidity: Proper temperature and humidity need to be maintained to maximize the life and maintain the quality of the harvested fruits and vegetables. Fresh fruits need to be stored at low temperature and high humidity conditions for reducing respiration and slowing down the metabolic processes. Different optimal storage temperatures and relative humidity are specified for different produce. The variations in temperature and humidity in the cold storages should be within specified ranges.

CO_2 level: CO_2 level within the cold store chamber should be kept below 4,000 ppm during loading and 2,000 ppm during holding. To maintain the CO_2 level less than 4,000 ppm, 2–6 air changes per day is desirable.

Air circulation: The recommended design for a multi-commodity cold storage facility is about 150-170 m^3/hr per tonne of holding product. The air flow rate is maintained between 30–70 m^3/hr after the produce reaches the chamber at the desired temperature.

The major process steps in a cold storage facility are depicted in Figure 3.4.

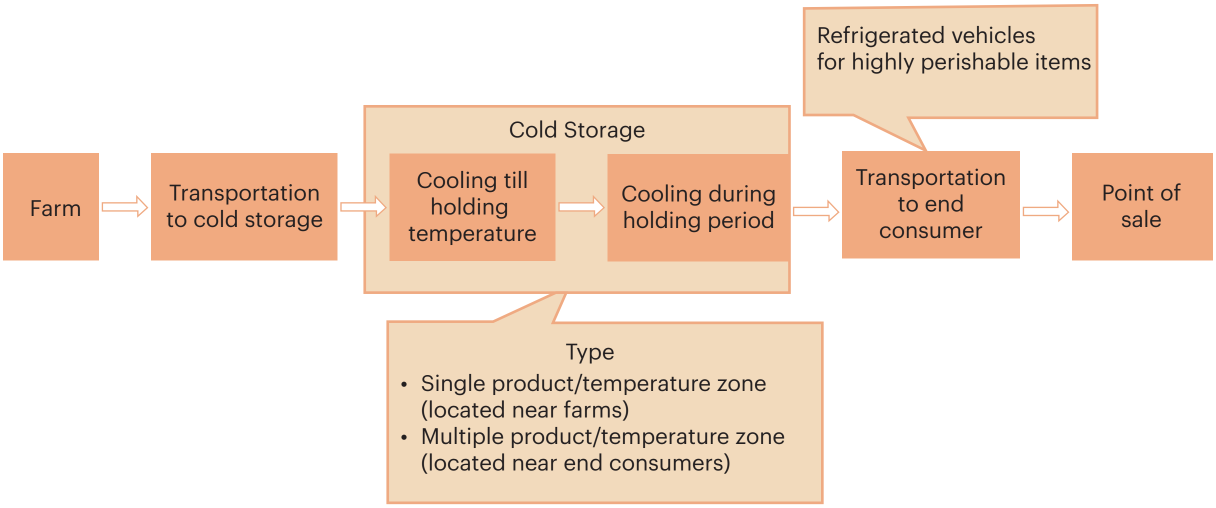


Figure 3.4: Major process steps in cold storage facility

3.2 Electricity and Demand Profile

The electricity consumption in a cold storage varies with ambient temperature and relative humidity. The electric motors associated with refrigeration compressors, evaporator air circulation fans, condenser pumps and cooling tower fans account for the major loads in a cold storage unit. The monthly and section-wise electricity consumption is shown in Figure 3.5.

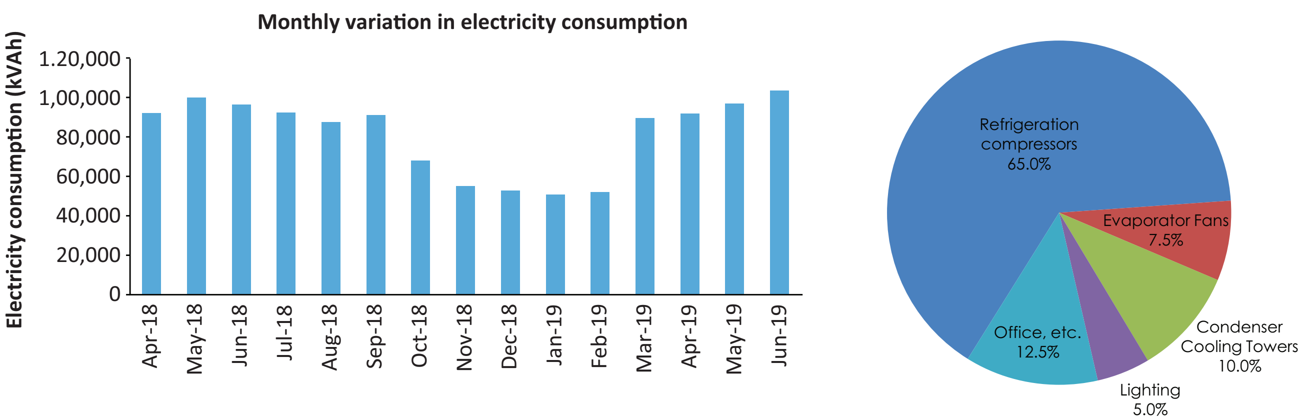


Figure 3.5: Monthly and section-wise electricity consumption

The contract demand of the cold storage units varies between 225 kVA to 350 kVA. The average demand utilization factor is about 90%. The load factor is between 33-64%. The demand utilization and load factors of selected cold storage units are shown in Figure 3.6.

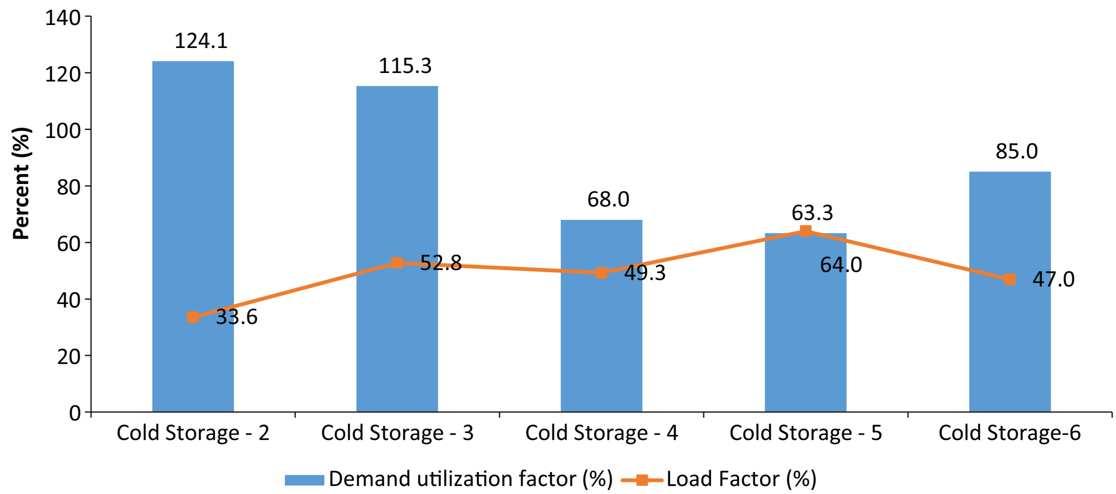


Figure 3.6: Demand utilization and load factors of selected cold storage units

3.3 Technologies Employed

The cold storage units are usually multi-commodity facilities having multiple cold chambers. In addition, there are anterooms, docking/grading/sorting area, crates/pallet storage area, machine room, electrical room, etc. Some of these areas and energy-intensive equipment are detailed below.

Refrigeration system: The refrigeration system consists of refrigeration compressors, atmospheric/ evaporative condensers or cooling towers, and fan coil units. Both reciprocating type multi-cylinder compressors (working on ammonia) and screw type compressors and scroll compressors (working on refrigerant gases like R134a and R404a) are in use. In most units, the refrigeration systems are operated at maximum load with manual control. Electric motors associated with the refrigeration system are of standard efficiency class. Use of motors which have been rewound more than once is common. Some cold storages, equipped with bunker coils, use conventional type ceiling fans (75 W) in the cold chambers. Mild steel piping is used for interconnecting the compressor, condenser, and cooling units. The cold Insulation of piping, valves and flanges are often damaged or missing. Some common refrigeration sub-systems used are shown in Figures 3.7 and 3.8.

Figure 3.7: Common refrigeration system (L-R) Reciprocating ammonia compressor, scroll compressor, screw compressor

Figure 3.8: Atmospheric condenser unit for ammonia compressors

Cold chambers: The cold chambers for long/medium-term storage have capacities between 250 metric tonne (MT) to 1,250 MT. For transit/short-term storage, the chamber capacities range between 30 MT to 150 MT. The walls of chambers are made of brick or solid concrete blocks and have sand and cement plaster. The roof is either made of reinforced cement concrete (RCC) or is a truss structure with corrugated galvanised iron (GI) sheet cover. The cold chambers are provided with appropriate insulation on the walls and ceiling. The doors are often fitted with strip curtains to prevent air infiltration.

Figure 3.9: Cold chamber

Lighting/illumination system: Use of compact fluorescent lamps (CFLs) and fluorescent tube lights (T-8/T-12) is common in cold chambers, machine room and other areas. Few facilities use incandescent lamps in cold chambers and mercury vapour lamps in the shed and common areas. LED lamps are also used in some sections.

Figure 3.10: Fluorescent tube lights

3.4 DSM/EE Opportunities

Common energy efficient technologies which can be adopted by the cold storage facilities are discussed below.

3.4.1 Premium efficiency class electric motors

The standard and rewound motors can be replaced with premium efficiency class (IE3) motors. The DSM/EE opportunity is summarised in Table 3.1.

Table 3.1: Energy saving opportunities in electric motors

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of standard/rewound motors with IE3 motors	➢ Standard efficiency class motors ➢ Multiple rewound motors	Premium efficiency class (IE3) motors (IS12615)	5-7%	<2 years

3.4.2 Energy efficient BLDC fans

The cold storages equipped with bunker type coils use ceiling fans for air circulation. Conventional fans quickly get heated-up adding to the air-conditioning load. The temperature of these fans were found to range be between 21°C to 30°C when the chamber temperature was between 4.5 °C to 6°C). The additional heat load due to the heating up of the fans was estimated to be 22 TR/fan annually. Compared to conventional ceiling fans, BLDC fans consume less power and also result in minimal heat generation. The DSM/EE opportunity is summarised in Table 3.2.

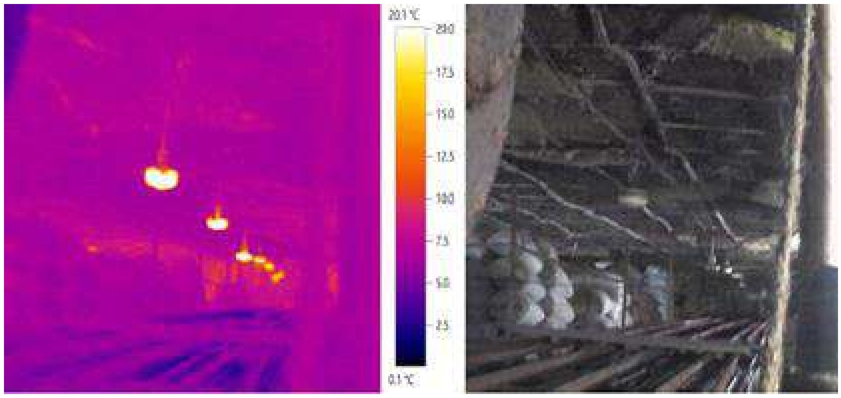


Figure 3.11: Thermal image of conventional ceiling fans in chambers

Table 3.2: Energy efficient BLDC fans

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of conventional fans with BLDC fans	➢ Conventional induction motor type ceiling fans ➢ Capacity: 70–75 W	➢ Energy efficient BLDC ceiling fans ➢ Capacity: 28–30 W	55–60%	<1 year

3.4.3 Use of LED illumination system

The illumination system accounts for 4% to 7% of the total electricity consumption. Apart from higher energy consumption, use of inefficient lighting within the storage area adds to the refrigeration load. LED lights are more energy efficient and produce less heat. The DSM/EE opportunity is summarized in Table 3.3.

Table 3.3: LED tube lights & bulbs

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of FLTs with LED tube lights	➢ Fluorescent tube lights (T-8/T-12) ➢ Capacity: 44–52 W	➢ LED tube lights ➢ Capacity: 18/20 W	55–60%	< 0.5 year
Replacement of incandescent bulbs with LED bulbs	➢ Incandescent light bulb ➢ Capacity: 60/100 W	➢ LED light bulbs ➢ Capacity: 7/9 W	80–85% (in power consumption)	< 0.5 year

3.5 Key Technologies and Energy Saving Potential

The key technologies which can be aggregated to promote DSM in cold storage sector include the following:

- Premium efficiency class (IE3) motors
- BLDC ceiling fans and
- Energy efficient LED lighting.

Based on the assessment studies conducted, an overall electricity saving potential between 5.5% to 12.5% is estimated in the cold storage sector.

Annex 4: Steel/Foundry

The steel and foundry units in the licensee area of Tata Power DDL are located in the industrial areas of Badli, Najafgarh Road and GT Karnal Road in north Delhi. The locations of these units are shown in Figure 4.1. These units are involved in processing of a variety of iron and steel products for equipment fabricators, utensil and appliance manufacturers and other end-users. Some of the leading steel/foundry units in the distribution licensee area include Grover Steels (India), Goel Steel Corporation, Bhawani Steel and Shri Rishab Industries.

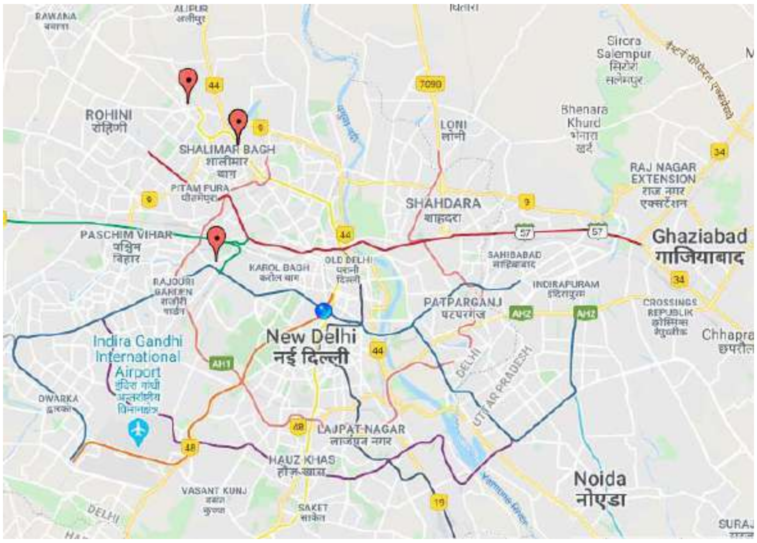


Figure 4.1: Clusters of steel/foundry industries in Delhi

4.1 Production Process

The steel/foundry units can broadly be divided into two categories, (i) foundry (melting) units (ii) metal processing (steel rolling, sheet metal, heat treatment, etc.) units.

The generic manufacturing processes adopted by them are described below.

4.1.1 Foundry (melting) units

The manufacturing process adopted by them are detailed below.

Charging: The metallics such as bought-out scrap, returns, and ingots are weighted and charged into the furnace.

Melting: The iron melting units use electric induction furnaces. The aluminium melting units use oil/gas fired crucible furnaces. The chemistry of the molten metal is adjusted by the addition of alloys and tapped when the required temperature is achieved.

Pouring: The molten metal is transferred using ladles and poured into the moulds.

Knock-out: The castings are separated from moulds after a certain period.

Finishing: The finishing operation involves shot blasting/cleaning and machining. Heat treatment is also undertaken for certain products.

A simplified process flow diagram of a foundry is shown in Figure 4.2.

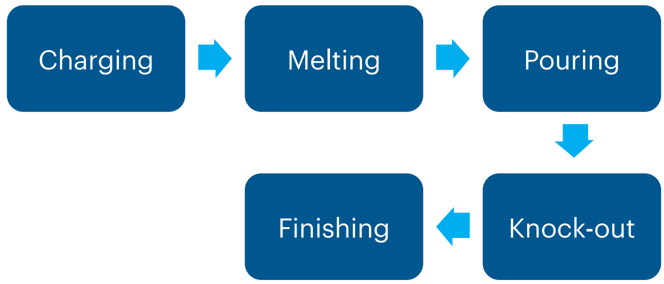


Figure 4.2: Process flow in foundry unit

4.1.2 Metal processing units

The metal processing units encompass a wide range of manufacturing processes including material preparation, hot and cold rolling, annealing/ heat treatment, machining/sizing and so on. The process flow diagram of a typical metal processing unit is shown in Figure 4.3.

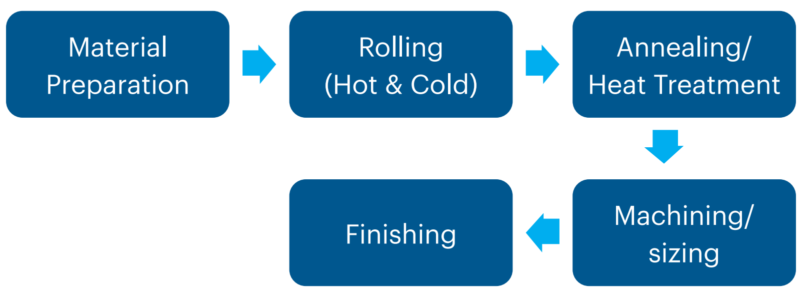


Figure 4.3: Process flow in metal processing unit

4.2 Electricity and Demand Profile

The average load of a typical unit is about 54% of the contract demand. The load varies between 40% to 90% during the day. A sharp increase in the load can be observed after 9:30 hours. The maximum electricity consuming centres are melting/heating operations, process cooling, air compressors, space cooling, and lighting. The variation in demand during a working and non-working day and the section-wise share of energy consumption is shown in Figure 4.4.

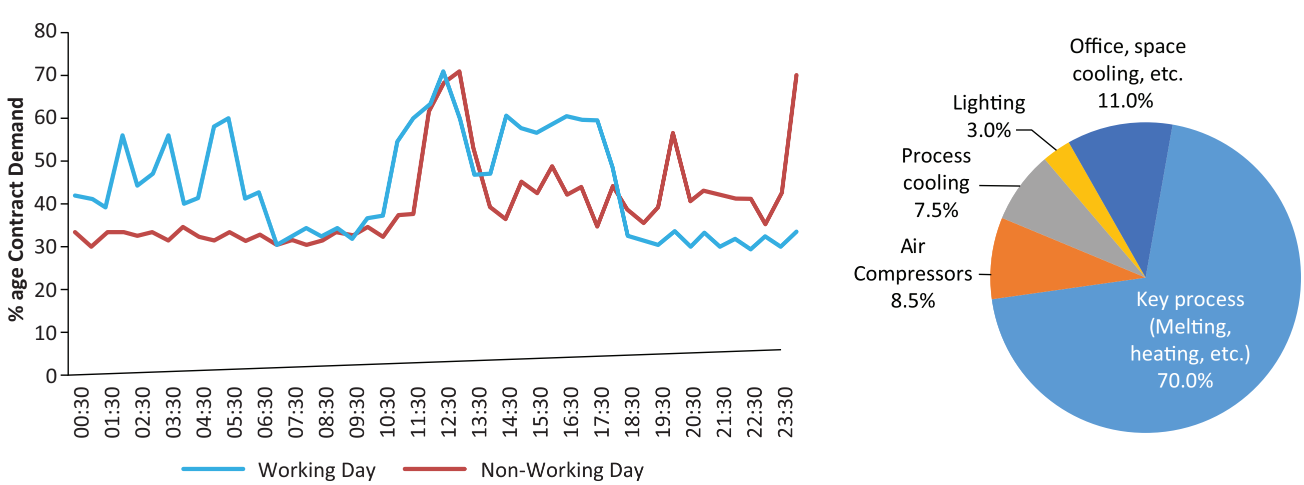


Figure 4.4: Typical demand pattern and section-wise electricity consumption

The contract demand of the units varies from 50 kVA to 1,000 kVA. The average demand utilization factor is 85%. In some units, the demand exceeds the contract demand. The load factor varied between 10% to 42%. The variations in the demand utilization and load factors of some steel/foundry units are shown in Figure 4.5.

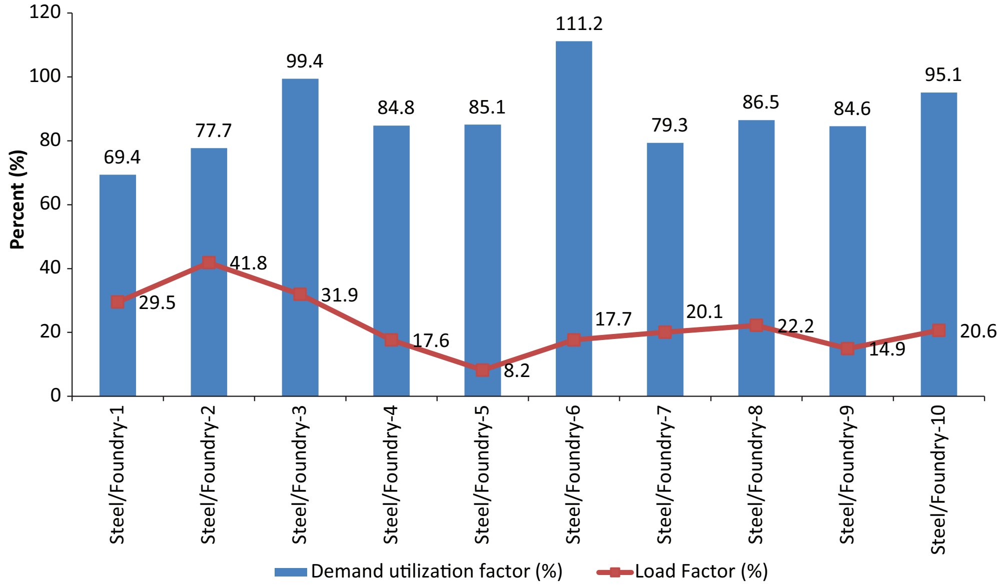


Figure 4.5: Demand utilization and load factors of steel/foundry units

4.3 Technologies Employed

There is a large variation in the technologies used by the steel/ foundry units. This is primarily because of the wide range of products manufactured by them. The major energy-consuming sections are melting/ reheating furnace, rolling and auxiliaries. Figures 4.6 and 4.7 show some of these sections.

Common technologies which can be agglomerated in these industries include the following:

Figure 4.6: Reheating furnace (sheet metal)

Figure 4.7: Steel rolling

Electric motor: The processing units use hot and cold rolling mills and associated machines to carry out operations like sizing, cutting, turning, finishing, etc. These machines use standard efficiency class motors with belt-pulley drives Most of the electric motors have been rewound multiple times. The motors are connected to the machines using inefficient belt and pulley systems.

Air compressor: Compressed air is mainly used as instrumentation air and for cleaning and housekeeping purposes. Both tank-mounted reciprocating air compressors and rotary screw air compressors are in use. The electrical rating of these compressors range from 7.5 hp to 40 hp.

Lighting/illumination system: Use of compact fluorescent lamps (CFLs) and fluorescent tube lights (T-8/T-12) are common. Some units still use incandescent lamps and mercury vapour lamps. Few units have adopted LED lamps.

4.4 DSM/EE Opportunities:

Common energy-efficient technologies that can be adopted by these facilities are discussed below.

4.4.1 Premium efficiency class electric motors

Standard efficiency class motors are used in equipment like hot and cold rolling mills, cutting machines, lathe machines, air compressors, pumps, fans and so on. The use of re-wound motors is common. The standard/rewound motors can be replaced with premium efficiency class (IE3) motors. The DSM/EE opportunity is summarized in Table 4.1.

Table 4.1: Energy saving opportunities in electric motors

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of standard/rewound motors with IE3 motors	➢ Standard efficiency class motors ➢ Multiple rewound motors	➢ Premium efficiency class (IE3) motors (IS12615)	5-7%	< 2 years

4.4.2 Energy efficient compressed air system

The actual demand of compressed air varies between 65% to 70% of their rated compressor capacity. In many units, the generation compressed air pressure was 10.0–12.5 kg/cm^2(g) against a process requirement of 5.0–6.5 kg/cm^2 (g). Optimising the compressed air generation pressure, replacing the inefficient reciprocating compressors with energy efficient reciprocating/screw compressors and adoption of inverter (variable frequency drive) with super premium efficiency (IE4) class motors screw air compressors would save energy. These DSM/EE opportunities are summarised in Table 4.2.

Table 4.2: Energy efficient compressed air system

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Optimum setting of compressed air generation pressure	➢ Set pressure: 10.0–12.5 kg/cm^2(g) ➢ End use pressure requirement: 5.0-6.5 kg/cm^2 (g) (max.)	➢ Set pressure: 6–7 kg/cm^2(g) ➢ End use pressure requirement: 5.5 kg/cm^2(g) (max.)	12-15"%	Immediate
Replacement of screw type air compressors with new compressors equipped IE4 motor and VSD system	➢ Fixed speed, screw type air compressor ➢ Capacity utilization: 65-70"% ➢ Unload period: 30–35% ➢ SPC: 0.18-0.22 kW/CFM	➢ SPC: 0.15-165 kW/CFM ➢ No unloading losses	15-17"%	2-3 years
Replacement of reciprocating (5.5 – 18.5 kW) compressor with screw type air compressor	➢ SPC: 0.195-0.255 kW/CFM ➢ On-Off mode	➢ SPC: 0.165-0.185 kW/CFM ➢ Variable speed mode	12-23%	2-3 years

4.4.3 Use of LED illumination system

The replacement of the conventional lamps with energy efficient LED lights will reduce the lighting demand and increase the life of the lamps. The DSM/EE opportunities are summarised in Table 4.3.

Table 4.3: LED tube lights & bulbs

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of FLTs with LED tube lights	➢ Fluorescent tube lights ➢ Capacity: 44-52 W	➢ LED tube lights ➢ Capacity: 18/20 W	55-60%	< 0.5 year
Replacement of incandescent bulbs with LED bulbs	➢ Incandescent light bulbs ➢ Capacity: 60/100 W	➢ LED light bulbs ➢ Capacity: 7/9 W	80-85%	< 0.5 year
Replacement of MVL/ SVL with LED bay/flood light (shed light)	➢ MVL/SVL lamps ➢ Capacity: 75/250 W	➢ LED lights ➢ Capacity: 35/125 W	55-60%	<1 year

4.4.4 Energy efficient BLDC fans

The use of conventional wall-mounted, pedestal and ceiling fans for space cooling purposes is common. These fans are equipped with single-phase induction motor of capacity between 65-90 W. These conventional air circulation fans could be replaced with energy-efficient BLDC fans. BLDC fan consumes 28-35 W and delivers the same amount of air. The DSM/EE opportunity is summarised in Table 4.4.

Table 4.4: Energy efficient BLDC fans

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of conventional fans with BLDC fans	➢ Conventional induction motor type fans ➢ Capacity: 65-90 W	➢ Energy efficient BLDC fans ➢ Capacity: 28-35 W	55-60%	<1 year

4.5 Key Technologies and Energy Saving Potential

The key technologies which can be aggregated to promote DSM in steel/foundry sector include the following:

- Premium efficiency class motors,
- Energy efficient air compressors,
- BLDC fans and
- Energy efficient LED lighting.

Based on the assessment studies conducted, an overall electricity saving potential between 5.5-19.5% is estimated in the sector.

Annex 5: Textile

Most of the textile units within the licensee area of Tata Power DDL are located in the industrial areas of Najafgarh Road, Kirti Nagar and Badli in west and north Delhi. These locations are shown in Figure 5.1. These textile units are involved in the manufacture of a variety of yarns, fabrics and hosiery products. These units primarily cater to the demand of Delhi/NCR region and supply their products to downstream processors and wholesalers. Some of the leading textile units in the distribution licensee area a include Supreme Hosiery Factory, V S Traders, and Kishore Hosiery Works.

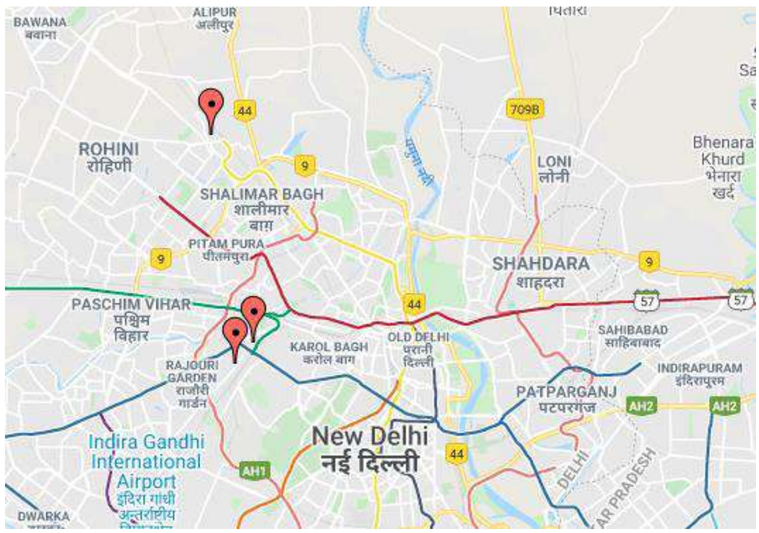


Figure 5.1: Concentrations of textile units in Delhi

5.1 Production Process

The manufacture of stretchable or elastic yarns is a semi-automated process involving raw material preparation, winding and twisting, doubling and packing. A process flow diagram of a yarn manufacturing unit is shown in Figure 5.2.

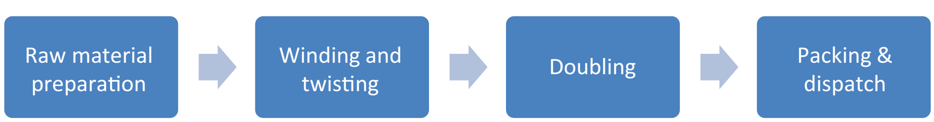


Figure 5.2: Simplified process of yarn production

The process starts with the preparation of the raw material. The generic process steps followed in yarn manufacturing are briefed below.

Winding and twisting: In winding, the string is wound on bobbins through an electric motor driven winding machine. A winding machine is shown in Figure 5.3. Thereafter, two separate strings are twisted together and wound.

Figure 5.3: Winding machine

Doubling: During this step, the strings are doubled for higher strength. The process also increases smoothness, evenness, lustre, uniformity, and compactness.

Finally, the bobbins are collected and packed for dispatch as per the required gauge.

5.2 Electricity and Demand Profile

The major electricity consumption areas in these units are in processing section (58%), space cooling (16%) and air compressors (11%). The end-use electricity consumption pattern in a typical unit is shown in Figure 5.4.

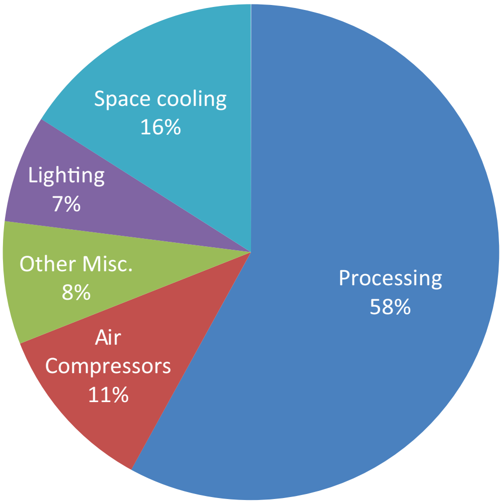


Figure 5.4: End use consumption pattern

Most of the textile units operate in two shifts. The contact demand of the units varies in the range of 75 kVA to 250 kVA. The average demand utilization factor is close to 60%. The load factor range between 18% to 55%. The variations in demand utilization and load factors of selected textile units are shown in Figure 5.5.

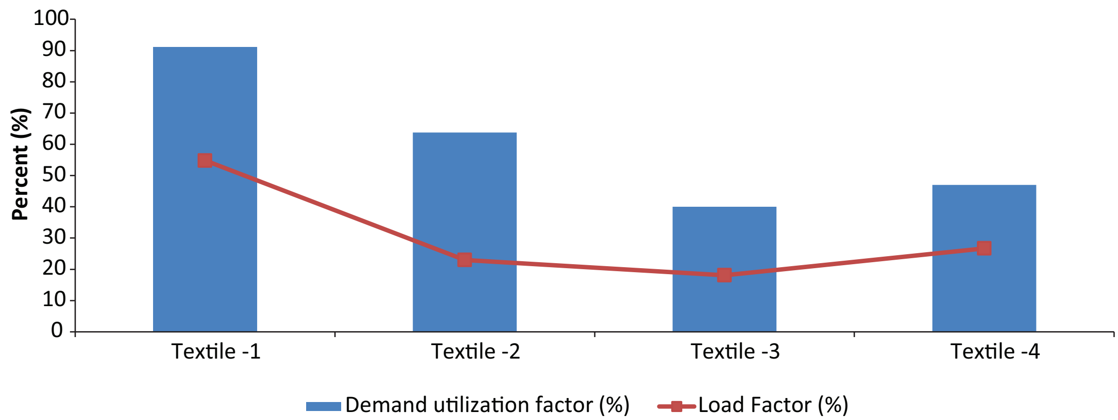


Figure 5.5: Demand utilization and load factors of textile units

The average power factor in these units range between 0.94 to 0.98. Lower power factor leads to increased electricity cost as "kVAh" based billing is applicable for the industrial consumer category. The units have provided fixed capacitor banks at the main incomer and load-ends for power factor correction requirements.

5.3 Technologies Employed

Most of these industries are involved in the processing of raw material to make yarn. The yarn is then used for the manufacture of fabrics, bandages and different hosiery items like socks, stockings. gloves etc. Some of the major energy consuming equipment in them are described below.

Electric motors: The electric motor driven systems are the largest energy consumers in the processing and winding of yarn. The motors used in processing are of standard efficiency class and have been rewound multiple times. The ratings of these motors range between 1.2 kW to 5.5 kW. Most of these motors operate at low or partial loads. The power factor of these motors range between 0.55–0.82.

A typical process section is shown in Figure 5.6.

Figure 5.6: Electric motor driven systems in textile units

Other equipment: The other major energy consuming equipment in these units are the air compressors, space cooling fans and lighting. The air compressors are commonly tank mounted reciprocating type of capacity between 2.2 kW to 5.5 kW. The maximum pressure required in most of the applications is below 5.5 kg/cm². Use of conventional type ceiling and pedestal fans is common for space cooling requirements. The units mainly use fluorescent tube lights (T-8/T-12). Few units still use incandescent lamps and compact fluorescent lamps in the shed and common areas.

5.4 DSM/EE Opportunities

Common energy-efficient technologies that can be adopted by the textile processing industries are discussed below.

Premium efficiency class electric motors

Attractive energy savings is possible by replacing the standard motors with premium efficiency class (IE3) motors. The DSM/EE opportunity is summarised in Table 5.1.

Table 5.1: Energy saving opportunities in electric motors

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of rewound motors with premium efficiency class IE3 motors	➢ Standard efficiency class motors ➢ Multiple rewound motors	➢ Premium efficiency class (IE3) motors ➢ (IS12615)	5-7%	< 2 years

Use of LED illumination system

The share of electricity consumption in the illumination system ranges between 4-8%. Replacement of the conventional lamps with energy efficient LED lights will reduce the lighting demand as well as increase the life of the illumination system. The DSM/EE opportunity is summarized in Table 5.2.

Table 5.2: LED tube lights & bulbs

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of FLTs with LED tube lights	➢ Fluorescent tube lights ➢ Capacity: 44-52 W	➢ LED tube lights ➢ Capacity: 18/20 W	55-60%	< 0.5 year
Replacement of incandescent bulbs with LED bulbs	➢ Incandescent light bulb ➢ Capacity: 60/100 W	➢ LED light bulbs ➢ Capacity: 7/9 W	80-85%	< 0.5 year

Energy efficient BLDC fans

The conventional fans can be replaced with energy efficient BLDC fans. The BLDC fans consume 28-35 W and deliver the same amount of the air. The DSM/EE opportunity is summarized in Table 5.3.

Table 5.3: Energy efficient BLDC fans

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of conventional fans with BLDC fans	➢ Conventional induction motor type fans ➢ Capacity: 65-90 W	➢ Energy efficient BLDC fan ➢ Capacity: 28-35 W	55-60%	<1 year

5.5 Key Technologies and Energy Saving Potential

Key interventions and technologies, which can be aggregated to promote DSM in textile units include the following:

- ➢ Premium efficiency class motors
- ➢ Energy efficient LED lighting
- ➢ Energy efficient BLDC fans

In addition to the technology up-gradation options, unit-specific measures like improved power factor correction system would help in reducing electricity costs.

The assessment studies show that there is a potential to save electricity between 4.5% to 19% in these units.

Annex 6: Dal and Flour

Most of the dal and flour mills under the licensee area of Tata Power DDL are located in the industrial areas of Lawrence Road, GT Karnal Road, Bawana, and Keshavpuram. These locations are shown in Figure 6.1. These industries process a variety of dals (pulses) and flour (maida). Most of these units cater to the Delhi and NCR region and supply their products through wholesalers or sell directly to bulk purchasers like food processing units. Some of the leading mills in the distribution licensee area include Rajdhani Flour Mills, Golden Roller Flour Mills, Mittal Food Products, and Victoria Foods.

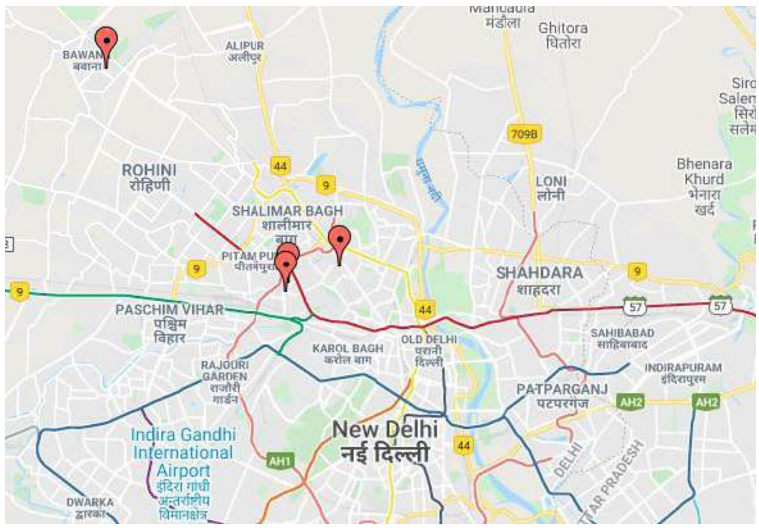


Figure 6.1: Locations of dal & flour mills in Delhi

6.1 Production Process

6.1.1 Dal mill

The common dals processed by these mills include bengal gram or chickpea (chana), pigeon pea (tur/arhar), cowpea (lobia), black gram (urad), green gram (moong), lentils (masur), peas (matar). The process involves de-husking, splitting and polishing of the whole dals. The process flow diagram of a dal mill is shown in Figure 6.2.

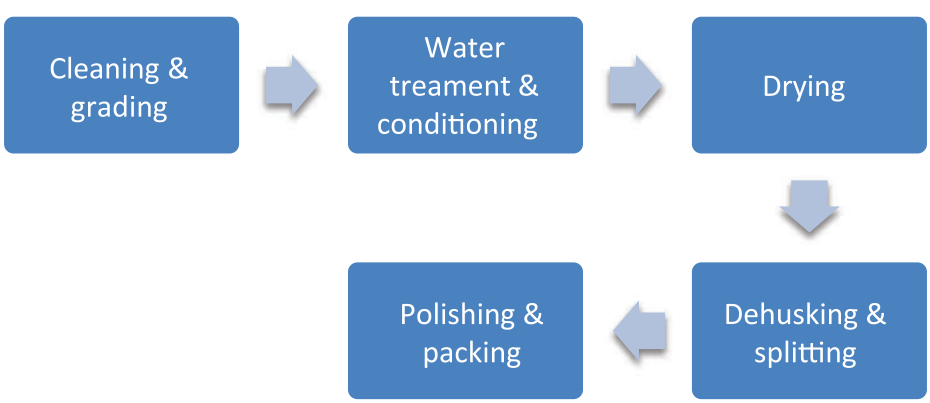


Figure 6.2: Process flow in a dal mill

Cleaning and grading: Pulses received by the mill are cleaned and graded. Air screen or vibratory inclined screen graders and cleaners are typically used in this section. The air-screens are more effective but they consume higher energy.

Water treatment and conditioning: Water is added to the whole dal to facilitate splitting with less breakage.

Drying: Apart from natural sun drying, use of wood or fossil fuel based drying is common. Hot air between 60 °C to 120 °C is generated for drying in a closed chamber dryer.

Dehusking and splitting: Dehusking or dehulling is the removal of seed coat from the pulse. Traditionally, attrition type mills are used for dehulling and splitting processes where two stones are oriented either horizontally or vertically and the gap between the stones are adjusted to the seed size. A rolling mill with carborundum stone or emery roller can also be used to dehusk the pulses. Factors affecting splitting and dehulling include moisture content, seed size and uniformity of size, and seed hardness. Too high or low moisture can increase the breakage and fine particles, thus the drying process is critical after soaking/tempering.

Polishing and packing: In this operation, pulses are imparted with a glazing appearance to improve consumer's acceptance and market value. Finally, the pulses are packed as per market requirements.

6.1.2 Flour mill

Flour milling involves breaking the wheat grain into its constituents, that is, germ, bran, and endosperm. The process flow diagram of a flour mill is shown in Figure 6.3.

Cleaning: The wheat is cleaned to remove impurities such as sticks, stones, and foreign materials. Electric vibrating screens are used for separating the impurities.

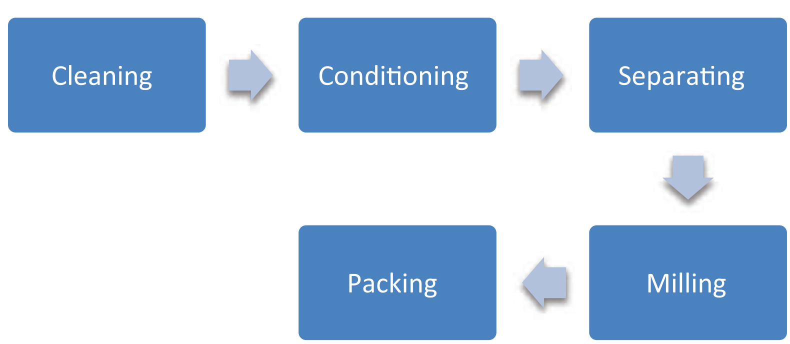


Figure 6.3: Process flow diagram of a flour mill

Conditioning: At this stage, the soaking of the wheat in water takes place for easy removal of the bran. Conditioning is done before milling to ensure that the moisture content is uniform throughout the grain.

Separating: In separating or hulling section, the grain goes through a series of rollers rotating at various speeds. The rolls only split the wheat grain open to separate the inner white portion form the bran.

Milling: The wheat is ground by a machine that crushes it into pieces. It is then put through sifters from which the meal obtained starts out course. With repeated grinding and sifting, the meal becomes fine flour, wheat germ and wheat bran.

Packing: The different types of flour (white flour, brown flour and whole meal flour) are packed as per the market requirements.

6.2 Electricity and Demand Profile

The average daily load is about 55% of the contract demand. The load varies between 10% to 80% during the day. The sharp decline in demand during the morning and evening is due to change in shift. The capacity utilization of the plant and hence the electrical demand usually increase on Sundays due to easy movement of trucks. The demand pattern of a typical dal mill is shown in Figure 6.4.

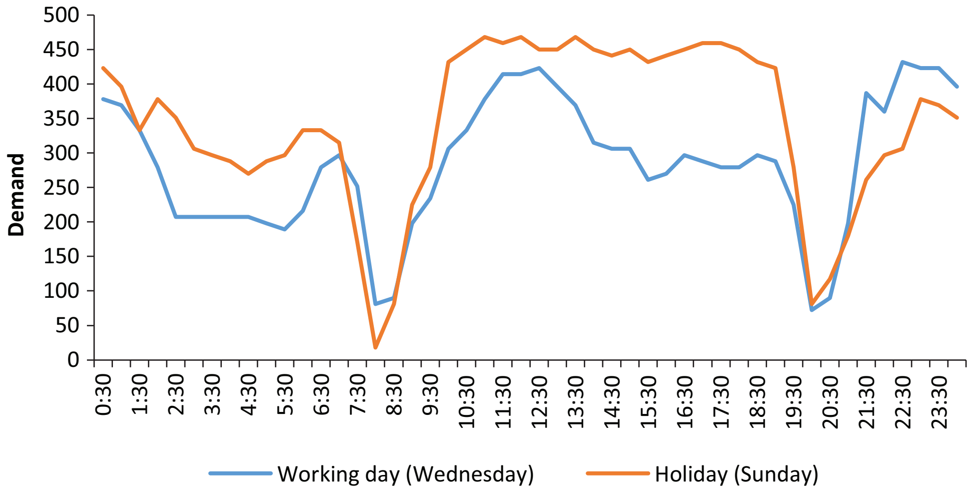


Figure 6.4: Typical load profile of a dal mill

The contract demand varies between 75 kVA to 1,500 kVA. The average demand utilization factor is 86%. The load factor usually ranges between 65% to 100%. In some cases, it overshoots the contract demand. The variations in the demand utilization and load factors of some mills are shown in Figure 6.5.

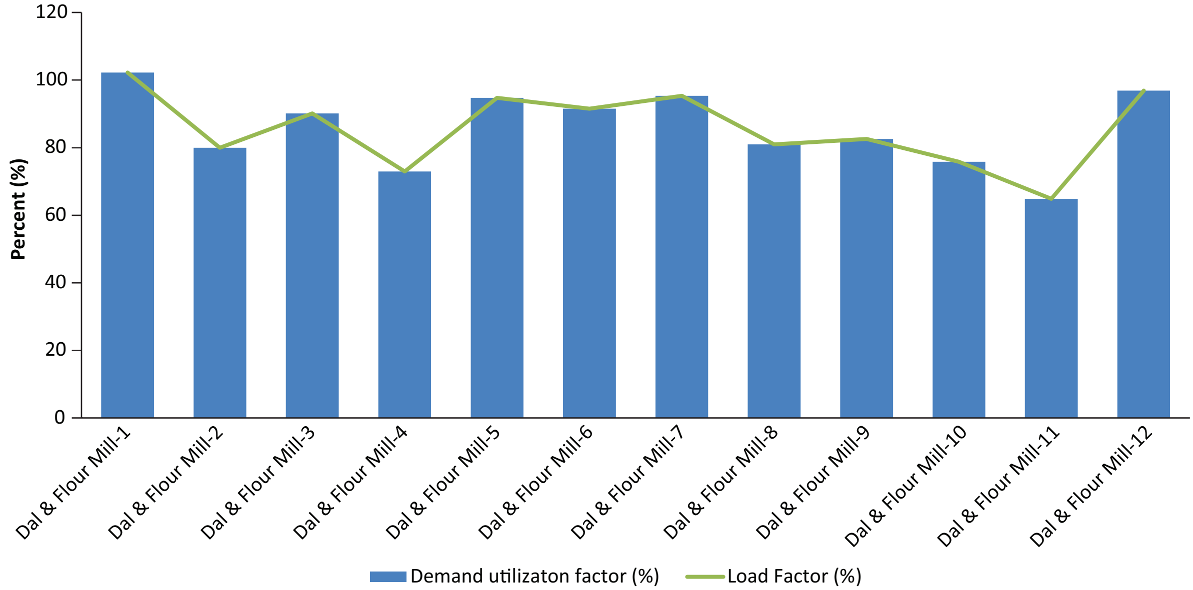


Figure 6.5: Demand utilization and load factors of dal and flour mills

The average power factor in the units varies between 0.94 to unity. A power factor below unity leads to higher electricity cost as "kVAh" based billing is applicable for the industrial consumer category. Most units have installed fixed type capacitor banks to maintain power factor and relatively few units have installed an automatic power factor correction system. The installed power factor correction system was often not working properly, resulting in a power factor between 0.94 and 0.98.

6.3 Technologies Employed

The major energy consuming equipment used in these mills are the following:

Electric motors: Most equipment including vibrating screens, sieves, rollers, fans/blowers, conveyors and bucket elevators use electric motors.

Air compressors: The mills use compressed air for cleaning and conveying grains. The electrical rating of the air compressors ranges from 7.5 hp to 40 hp. Medium-sized mills use screw air compressors, while smaller-sized mills use reciprocating compressors.

Lighting/illumination system: The lighting provided is mainly compact fluorescent lamps (CFLs) and fluorescent tube lights (T-8/T-12) in the process and other areas. Few progressive units have adopted LED lamps in some of the sections.

6.4 DSM/EE Opportunities

Common energy-efficient technologies that can be adopted by these units are discussed below.

Figure 6.6: Old electric motors

6.4.1 Premium efficiency class electric motors

Use of standard efficiency class motors is widespread. Use of motors which have been rewound multiple times is common. These standard/rewound motors can be replaced with premium efficiency class (IE-3) motors. The DSM/EE opportunity is summarised in table 6.1

Table 6.1: Energy saving opportunities in electric motors

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of standard/rewound motors with IE3 motors	➢ Standard efficiency class motors ➢ Multiple rewound motors	➢ Premium efficiency class (IE3) motors ➢ (IS 12615)	5-7%	< 2 years

6.4.2 Compressed air system

While the maximum air pressure requirement in the processes is between 6-6.5 kg/cm^2(g), the generation pressure in the air compressors was found to range between 8.5–12.5 kg/cm^2(g). Also, the actual demand of compressed air is much below (35-65%) the rated capacity of the compressors.

Since the compressed air demand is fluctuating, adoption of air compressor with inverter (variable frequency drive) and super-premium efficiency (IE4) class motor is recommended. These compressors maintain the desired pressure and volume of air by increasing or decreasing the speed of the rotor, thus reducing power consumption.

Both reciprocating and screw type air compressors are used. While the larger units use rotary screw type compressors, the smaller units use tank-mounted reciprocating units. Sometimes, multiple sets of tank-mounted reciprocating compressors are used. The specific power consumption (SPC) of these air compressors was observed to be in the range of 0.185-0.270 kW per CFM. To save energy, these inefficient reciprocating air compressors should be replaced with either energy efficient reciprocating compressors or screw type air compressors. The DSM/EE opportunities are summarised in Table 6.2.

Table 6.2: Energy saving measures in compressed air system

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Optimum setting of compressed air generation pressure	➢ Set pressure: 8.5–12.5 kg/cm^2(g) ➢ End user pressure requirements: 6.0-6.5 kg/cm^2(g)	➢ Set pressure: 6.5–7 kg/cm^2(g) ➢ End user pressure requirements: 6.5 kg/cm^2(g)	10-15%	No cost measure
Rotary screw type air compressors with IE4 efficiency class motor and VSD system	➢ Fixed speed, screw type air compressor ➢ Capacity utilization: 35-65% ➢ SPC: 0.185-0.270 kW/CFM	➢ SPC: 0.15-165 kW/CFM ➢ No unloading losses	15-35%	1-3 years
Replacement of tank-mounted reciprocating (5.5–18.5 kW) by rotary screw type air compressors	➢ SPC: 0.185-0.270 kW/CFM ➢ On-OFF mode	➢ SPC: 0.15-0.165 kW/CFM ➢ Variable speed mode (optional)	12-23%	1-3 years

6.4.3 Use of high-efficiency LED illumination system

The share of electricity consumption in the illumination system ranges between 3% to 9%. The replacement of the conventional lamps with energy efficient LED lights will reduce the lighting demand and increase the life of the lamps. The DSM/EE opportunity is summarized in Table 6.3.

Table 6.3: LED tube lights and bulbs

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of FLTs with LED tube lights	➢ Fluorescent tube lights ➢ Capacity: 44-52 W	➢ LED tube lights ➢ Capacity: 18/20 W	55-60%	< 0.5 year
Replacement of incandescent bulbs with LED bulbs	➢ Incandescent light bulb ➢ Capacity: 60/100 W	➢ LED light bulbs ➢ Capacity: 7/9 W	80-85%	< 0.5 year

6.4.4 Energy efficient BLDC fans

The use of conventional ceiling fans for space cooling purposes is common. These fans could be replaced with energy-efficient BLDC fans. The DSM/EE opportunity is summarized in Table 6.4.

Table 6.4: BLDC ceiling fans

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of conventional fans with BLDC fans	➢ Conventional induction motor type fans ➢ Capacity: 65-90 W	➢ Energy efficient BLDC fans ➢ Capacity: 28-35 W	55-60%	<1 year

6.5 Key Technologies and Energy Saving Potential

Key technologies which can be aggregated to promote DSM in the sector include the following:

- ➢ Premium efficiency class (IE3) motors,
- ➢ Energy efficient air compressors
- ➢ Energy efficient LED lighting
- ➢ Energy efficient BLDC fans

Based on the assessment studies conducted, an overall electricity saving potential between 8.5% and 16.0% is estimated in the sector.

Annex 7: Other Sectors

Other industry sectors include rubber and plastics products, glass and ceramic products, jewellery, printing and miscellaneous items. These units are spread across industrial areas of Lawrence Road, Badli and Naraina in west and north Delhi. The location of these units is shown in Figure 7.1.

Some of the leading units in the distribution licensee area include Mansfield Conveyors, Asian Rubber Industries, and Tuli Offset Printers.

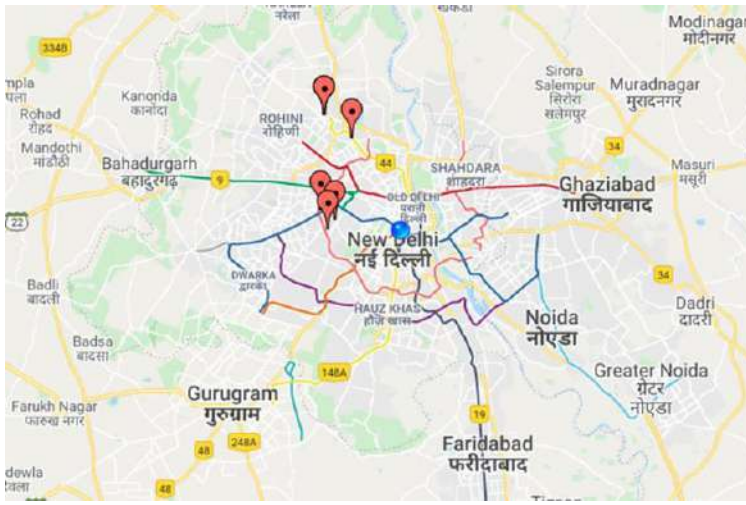


Figure 7.1: Location of other sectors in Delhi

7.1 Production Process

The major process steps in these units are the following:

Procurement of raw material: Different types of raw materials are procured depending on the nature of products manufactured by them. For example, the rubber and plastics units procure rubber and plastics granules, glass and ceramic units procure materials like uncut glass sheets and so on.

Processing: A number of different processes like extrusion, grinding, pressing, cutting, drying, printing and so on are used.

Packing and dispatch: The finished product is checked for quality, packed and dispatch.

7.2 Electricity and Demand Profile

The average load factor of these industries is 24% of the contract demand. The load factor ranges from 3% to 46%. The contract demand of these units range between 45 kVA to 530 kVA. The demand utilization is usually low. The average demand utilization factor is about 62%. The variations in the demand utilization and load factors of some units are shown in Figure 7.2.

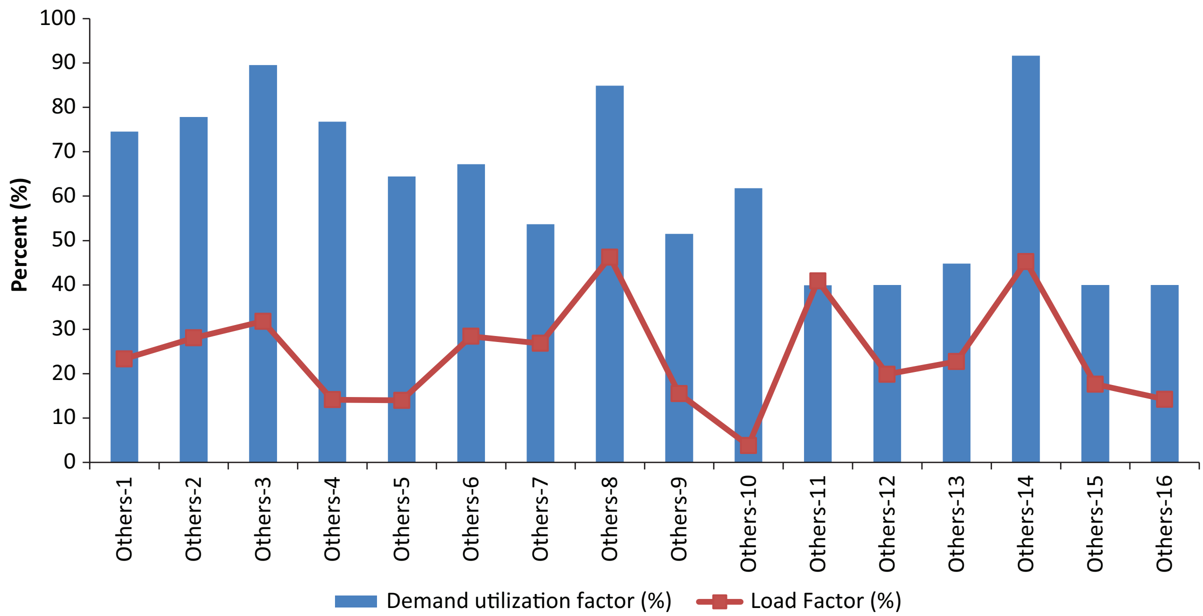


Figure 7.2: Demand utilization and load factors

The average power factor of these units range between 0.98 to unity. For power factor correction, the units have installed automatic power factor correction system at the main incomer and fixed capacitor banks at load-end.

7.3 Technologies Employed

The major energy consuming equipment used by these industries are described below:

Electric motors: Most of the machinery/equipment use squirrel cage induction type motors. These motors are of standard efficiency class.

Air compressors: Compressed air is mainly used for instrumentation and cleaning. The electrical rating of the compressors ranges from 3 hp to 25 hp. Both tank-mounted reciprocating type air compressors and fixed speed rotary screw type air compressors are in use.

Lighting/illumination system: The share of electricity consumption in the illumination range between 1% to 6%. Depending on the nature of operations carried out, luminance levels range between 150 lux to 350 lux. A number of units are still using CFLs and FLTs, while some have adopted LED lighting technologies.

Space cooling fans: The use of conventional wall-mounted, pedestal and ceiling fans for space cooling purposes is common. These fans are equipped with a single-phase induction motor of capacity between 65-90 W.

7.4 DSM/EE Opportunities

Common energy-efficient technologies that can be adopted by these units are discussed below.

7.4.1 Premium efficiency class electric motors

Use of standard efficiency class motors and rewound motors are common. The standard/rewound motors can be replaced with premium efficiency class (IE3) motors. The DSM/EE opportunity is summarized in Table 7.1.

Table 7.1: Energy saving opportunities in electric motors

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of standard/rewound motors with IE3 motors	➢ Standard efficiency class motors ➢ Multiple rewound motors	➢ Premium efficiency class (IE3) motors ➢ (IS 12615)	5-7%	< 2 years

7.4.2 Energy efficient air compressors

To save energy, inefficient reciprocating air compressors should be replaced with screw type air compressors with premium efficiency class (IE3) motors. The DSM/EE opportunity is summarized in Table 7.2.

Table 7.2: Energy efficient air compressors

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of tank-mounted reciprocating compressor (5.5 – 18.5 kW) by rotary screw type air compressor	➢ SPC: 0.19-0.26 kWh/CFM ➢ On-OFF mode	➢ SPC: 0.165-0.185 kWh/CFM ➢ Variable speed mode (optional)	12-23%	2-3 years

7.4.3 Use of high-efficiency LED illumination system

Replacement of the conventional lamps with energy efficient LED lights will not only reduce the lighting demand but also increase the life of the lamps. The DSM/EE opportunities are summarised in Table 7.3.

Table 7.3: LED tube lights & bulbs

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of FLTs with LED tube lights	➢ Fluorescent tube lights ➢ Capacity: 44-52 W	➢ LED tube lights ➢ Capacity: 18/20 W	55-60%	< 0.5 year
Replacement of incandescent bulbs with LED bulbs	➢ Incandescent light bulb ➢ Capacity: 60/100 W	➢ LED light bulbs ➢ Capacity: 7/9 W	80-85%	< 0.5 year

7.4.4 Energy efficient BLDC fans

These conventional air circulation fans could be replaced with energy-efficient BLDC fans. BLDC fans consume between 28-35W and delivers the same amount of air. The DSM/EE opportunity is summarised in Table 7.4.

Table 7.4: BLDC ceiling fans

Energy saving measure	Existing scenario	Proposed scenario	Energy saving potential (%)	Payback period
Replacement of conventional fans with BLDC fans	➢ Conventional induction motor type fans ➢ Capacity: 65-90 W	➢ Energy efficient BLDC fans ➢ Capacity: 28-35 W	55-60%)	<1 year

7.5 Key Technologies and Energy Saving Potential

Key technologies which can be aggregated to promote DSM include the following:

- Premium efficiency class (IE3) motors,
- Energy efficient air compressors
- BLDC ceiling fans
- Energy efficient LED lighting.

Based on the assessment studies conducted, an overall electricity saving potential between 3% to 11% is estimated in the sector.

Annex 8: Global Overview of MEPS for Electric Motors

Minimum requirements electric motors worldwide

Efficiency levels 3 phase induction motors (Low voltage <1000 V)	Efficiency classes IEC-60034-30-1, 2014 Global classes IE-Codel	Testing Standard IEC-60034-2-1, 2014 Incl. stray load losses	Performance standard Mandatory MEPIII National Policy Requirement	
Super Premium Efficiency	IE4	**Preferred Method II**	EU 28**	(75-200 Kw)
Premium efficiency	IE3		Canada	(0.75-375 kW)
			Mexico	(0.75-375 kW)
			USA	(0.75-375 kW)
			USA*	(0.18-2.2 kW)
			South Korea	(0.75-375 kW)
			EU 28**	(0.75-1.000 kW)
			Switzerland**	(0.75-375 kW)
			Turkey	(0.75-375 kW)
			Japan Toprunner	(0.75-375 kW)
			Israel	(7.5-375 kW)
			Singapore	(0.75-375 kW)
			Taiwan	(0.75-200 kW)
			Brazil	(0.12-370 kW)
			Ukraine***	(0.75-375 kW)
			Saudi Arabia	(0.75-375 kW)
High Efficiency	IE 2		Australia	(0.75-185 kW)
			Chile	(0.75-375 kW)
			China	(0.75-375 kW)
			Peru	(0.75-375 kW)
			Colombia	(7.5-375 kW)
			Iran	(7.5-375 kW)
			EU 28**	(0.12-0.75 kW)
			Israel	(0.75-5.5 kW)
			India	(0.37-160 kW)
			New Zealand	(0.75-185 kW)
Standard Efficiency	IE 1		Costa Rica	(0.75-375 kW)
		Summation of losses with load test: Additional losses Pu determined from residual loss	Vietnam	

Efficiency levels 3 phase induction motors (Low voltage <1000 V)	**Efficiency classes**	**Testing Standard**	**Performance standard**
	IEC-60034-30-1, 2014	**IEC-60034-2-1, 2014**	**Mandatory MEPIII**
	Global classes IE-Codel	**Incl. stray load losses**	**National Policy Requirement**
02 03 2020 Impact Energy Inc. & TPA advisors © EMSA 2020	I) output power 0.12 kW-1000 kW, 50 and 60 Hz. operated 2-.4-.-6 and 8-poles	II) for 3-phase machines direct online < 1kV rated output power <1000 kW III) Minimum Energy Performance Standard	*) Polyphase: eq. to IE3; single phase: IE2 levels or above **) Tier1: per 15/7/21; Option IE2+VSD removed (0.75-375 kW) Tier2: 1/7/2020; 1-phase>0.12 kW IE2; 0.75-75/200-1.000 kW IE3 ***) IE2 planned per Aug. 2018 ****) IE3 or IE2+VSD, per 1-9-2019 +2yrs for implementation

Annex 9: Unit-specific Technologies for Energy Savings

Apart from the four technologies for which demand was aggregated – premium efficiency class motors, energy-efficient air compressors, energy efficient BLDC fans and energy efficient LED lighting systems – there are a few other technologies which could be adopted by industries to reduce their operating energy cost. These technologies have been categorised as 'unit-specific technologies' because of the need for unit-specific customized or relatively small market size – factors which hinder demand aggregation and promotion under ESCOs business mode by the utility.

The key unit-specific technologies which are detailed in this section include the following:

- Automatic Power Factor Correction (APFC) system
- Maximum Demand (MD) controller
- Rooftop solar Photovoltaic (PV) system and
- Inverter type air conditioner (AC)

Descriptions of these technologies, along with cost-benefit analysis, are given in Table 9.1.

Table 9.1: Cost-benefit of unit specific technologies

S. No.	Unit-specific technologies	Image	Observations and recommendations	Average cost savings (₹ lakh/year)	Average investment (₹ lakh)	Simple payback period (years)
1	Installation of Automatic Power Factor Correction (APFC) system		The billed power factor of most MSMEs is less than the optimum value (i.e. unity or 0.999). Due to kVAh billing, lower power factor leads to higher electricity charges. It is recommended to improve the power factor close to unity (0.999) by adoption of suitable APFC system. This technology has a relatively high replication potential among MSMEs.	1.0 (Range: 0.15 – 3.5)	0.55 (Range: 0.25 -2.15)	0.5 (Range: 0.1-0.8)
2	Installation of Maximum Demand (MD) controller to optimise the contract demand		The average demand utilization among the surveyed MSMEs was found to be about 70%. However, as per the electricity tariff (i.e. two-part tariff with kVAh billing) the fixed costs or demand charges are 100% of the contract demand or sanctioned demand. Hence, low demand utilization factor in the industrial units leads to a higher average electricity cost. It is recommended to optimize the contract demand by the installation of an online MD controller[29] at the main incomer. The contract demand should be 110% of the billed demand. This technology has a medium replication potential among MSMEs.	1.6 (Range: 0.20-2.5)	0.30	0.2 (Range: 0.1-0.6)

[29] Basic specifications of MD controller include (i) measurement of basic power, energy and demand parameters (ii) Input voltage: 3 phase 4 wire; range - 415 VAC (-40% to +20%), 110 VAC (-40% to +20%) (iii) 4 relay output (iv) Programmable Real time clock to match EB meter's clock

Table 9.1: Cost-benefit of unit specific technologies

3	Installation of rooftop solar photovoltaic (PV) system		Adoption of rooftop solar PV system[30] will lead to a reduction in electricity bills. As a thumb-rule, 1 kW rooftop system requires 12 m^2 (130 ft2) of flat, shadow-free area (preferably south-facing). Actual sizing, however, depends also on local factors of solar radiation and weather conditions and shape of the roof. It is recommended to install a solar PV system on the rooftop where ever feasible. This technology has a medium replication potential among MSMEs.	3.7 (Assuming electricity cost of ₹. 8 to 9 per kWh)	16.5 (Assuming installation cost of ₹. 35,000 per kW[31])	4.5
4	Installation of inverter type air-conditioner (AC)		Use of unitary AC units (both split and window) is common among MSMEs. It was observed that the average SEC of 1.5 TR and 2.0 TR split AC is about 1.29 kW/TR (COP/EER[32] 2.72) and 1.34 kW/ TR (COP/ EER 2.62) respectively. In an inverter AC, the speed of the compressor motor is controlled according to the cooling requirement. This results in higher efficiency and better resilience to fluctuations in load. Thus, an inverter AC reduces operating costs and has a longer life. It is recommended to replace the traditional ACs with inverter type ACs. The EER/ISEER for the inverter AC is 4.5. This technology has a medium replication potential among MSMEs.	0.95 (Assuming savings of ₹. 20,000-35,00 per TR)	2.25 (Assuming cost ₹. 40,000 to 55,000 per TR[33])	2.5

30 Maximum permissible capacity of grid connected Solar PV system is 20% of distribution transformer (DT) capacity

31 Investment cost for grid-connected solar PV system per kW without any energy storage system

32 COP (coefficient of performance)/EER (energy efficiency ratio) indicates the heating/cooling performance of air conditioners. Both ratios are determined by the amount of heating and cooling generated by the air conditioning compared with the 1 kW of electricity it consumes.

33 Investment for inverter type BEE 5-star unitary air conditioning unit

Annex 10: Details of Electric Motors and Air Compressors

Electric motors

S. No.	Rated Capacity (kW)	Aggregated demand (Nos.)	Total connected load (kW)
1	0.75	5,800	4,347
2	1.1	6,300	6,929
3	1.5	12,980	19,465
4	2.2	17,260	37,973
5	3.7	12,850	47,548
6	5.5	12,350	67,907
7	7.5	9,580	71,813
8	11	9,830	1,08,097
9	15	5,420	81,262
10	18.5	4,410	81,577
11	22	6,680	1,46,902
12	30	5,420	1,62,524
13	37	2,770	1,02,554
14	45	1,640	73,703
15	55	1,640	90,081
16	75	2,020	1,51,185

Air Compressors

S. No.	Rated capacity (kW)	Energy efficient reciprocating air compressor	Rotary screw (VFD) air compressor	PMSM air compressors
1	1.5	711		-
2	2.2	995		-
3	3.7	995		-
4	5.5	2,842		568
5	7.5	1,421		426
6	11		853	853
7	15		284	284
8	18.5		142	1,990
9	22		284	2,132
10	30		-	426
11	37		-	142
12	45		-	142
13	55		142	-
14	75		-	142

Annex 11: Summary of Dissemination Workshop Held in Delhi

Background

The Energy and Resources Institute (TERI), jointly with a utility in Delhi, Tata Power DDL (Delhi Distribution Limited), organized a Dissemination Workshop on Demand Side Management (DSM)/Energy Efficiency (EE) Improvement Opportunities among SMEs on January 10, 2020 at Hotel Crowne Plaza, Rohini, New Delhi. The event was organised under the sub-project 'Assessment for aggregating DSM opportunities at utility level amongst industrial consumers for low carbon growth' of the project 'To provide research and information to power distribution utilities in India, enabling them to operate more efficiently and to help meet India's climate goals' being undertaken by TERI with support from MacArthur Foundation.

The objectives of the workshop were: (a) to share the results of walk-through energy audits conducted by TERI to identify DSM/EE opportunities among industrial consumers of the utility, and (b) to discuss opportunities to develop business models for demand response/demand aggregation. About 90 participants, consisting of SME entrepreneurs, staff of ESCOs and relationship managers from the partner utility attended the workshop.

Inaugural Session

Ms Kiran Gupta, Head (CS & KCG), Tata Power – DDL welcomed the participants, and outlined the partnership between Tata Power and TERI to study industrial (SME) electricity consumers with the aim of identifying opportunities for EE & DSM measures. She expressed satisfaction at the outcomes of the project, and urged the industry representatives to adopt the EE/DSM measures identified by the project and reap benefits through reduced electricity bills.

- Mr Girish Sethi, Senior Director, Energy Program, TERI thanked MacArthur Foundation for the support. He remarked that this partnership with Tata Power was the first of its kind between TERI and a power utility in the Delhi NCR region and expressed the hope that it would provide the foundation for more such meaningful partnership projects in future. He placed the project in the larger context of the need for India to improve EE and reduce carbon emissions in order to combat climate change. He added that TERI has considerable experience in working with the industrial sector, including energy audits (EA) in about 4,000 industries. He acknowledged the active participation by Tata Power in the Distribution Utilities Forum (DUF), a platform set up by TERI for the electricity distribution companies (discoms) across the country to share their experiences and learning. He added that the insights gathered from DUF, together with the feedback from consumers, will enable the creation of a document that can guide the government in formulation of policies related to EE in electricity distribution and usage.

Mr Sujoy Kumar Saha, Head - ESCO & HA, explained how an EA helps identify the 'little things' (i.e. low or no cost, easy-to-implement EE measures) that can save energy but are often missed out or overlooked by MSMEs in the course of day-to-day operations. Reiterating the need for electricity consumers to improve EE, he explained that low power factor (PF) and the use of inefficient technologies at the consumers' end leads to increased harmonics, which lowers the quality of grid electricity. Therefore, from the utility's point of view, it is vital to promote EETs and improve PF among consumers.

Mr Manish Kansal, representing the Industry Welfare Association in Lawrence Road, Delhi, shared how he has gained immensely by adopting energy efficiency in his factory. For example, he has installed capacitors in his unit's power panel as recommended by the EA. This simple measure has greatly improved his power factor and reduced his electricity bill because of avoided penalty. Also, he has already replaced about half the low-efficiency motors in his plant with premium efficiency IE3 motors.

Technical Session

Mr Prosanto Pal and Mr Pawan Kumar Tiwari, TERI, made a detailed presentation on "Assessment of DSM/ EE opportunities in industrial consumers". Some highlights from their presentation are summarised below:

- DSM programs among utilities can categorised under awareness (educational brochures, training programmes etc), technical assistance (energy audits) and financing (soft loans, energy service companies (ESCOs), rebates).
- Energy audits were conducted among 100 industrial consumers in three cities to identify DSM opportunities for scaling up using innovating mechanism.
- Electric motors accounted for major share (72%) of the total industrial load. Most (96%) of the motors are standard efficiency (IE1) class motors. Replacement of standard (IE1) motors with premium (IE3) class motors will result in an energy saving of 3.5 to 6.7%
- Air compressor is another commonly used equipment among industries. Energy saving of about 25% is achievable by adoption of energy efficient PMSM invertor air compressors.
- About 50% of lighting/lamps being used in industry are conventional and inefficient types (CFLs, FLT (T-8/T12), Mercury Vapour Lamps etc. Incandescent lamps are also in use. There is a good energy saving potential by replacing these with LED lamps/tubes.
- All industrial units using conventional ceiling fans. Adoption of BLDC fans will lead to an energy saving of 62%.
- Two ESCO models – vendor based ESCO and utility based ESCO was presented. Technologies requiring some technical assistance before implementation such as motors, air compressors can be replicated using vendor based ESCO model. The technologies which can be mass replicated such a EE lights, BLBC fans etc. are suitable for consideration under utility based model.
- There is a need for undertaking similar DSM studies in other utilities. Further, undertaking demonstration projects to implement the ESCO models jointly with utilities will be helpful.

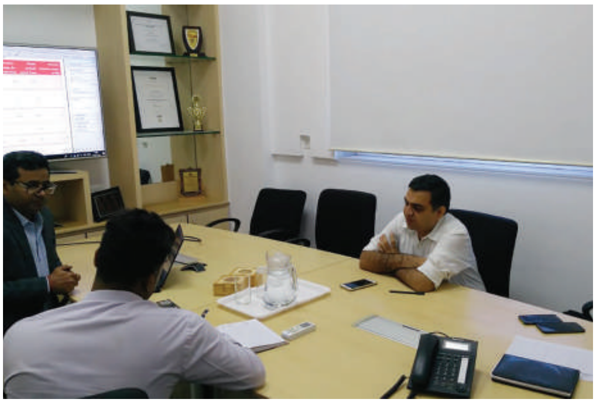
The presentation was followed by an interactive question and answer session with the participants. The session was moderated by Mr Ajay Koundal, Tata Power. The participants raised queries about adoption of the new EE technologies in their plant.

Key Takeaways/Way Forward

- Financial programs like rebates for energy efficient equipment would accelerate energy efficiency among industries. There is a need for policy advocacy for promotion of such programs in India.
- The participants acknowledged that there is need for training and capacity building of technicians and operators of SMEs on energy efficiency. Utilities and TERI should organise joint training programs for SME operators.
- Some pilot demonstration projects should be undertaken by utilities, jointly with vendors of energy efficient equipment to promote energy efficiency.

Annex 12: Summary of Dissemination Meeting Held in Mumbai

TERI had conducted 16 assessment studies among 16 SME industrial consumers of Tata Power in Mumbai. A dissemination meeting with the SME entrepreneurs was held on January 24, 2020 at the office of Tata Power Borivali Receiving Station, Mumbai.



Mr Manoj Salvi, Head-Customer Relationship Management, Tata Power Mumbai welcomed the participants. Mr Mahesh Joshi, Zonal Customer Manager (East), Tata Power Mumbai explained how these assessment studies have raised the awareness of their customers on energy efficiency and renewable energy measures

Pawan Kumar Tiwari, TERI, made a detailed presentation on the findings of the study among industrial consumers in Mumbai. The highlights from the presentation are summarised below:

- Electric motors accounted for major share (55%) of the total industrial load. Most (95%) of the motors are standard efficiency (IE1) class motors. Replacement of standard (IE1) motors with premium (IE3) class motors will result in an energy saving of 3.7 to 8.5%

- Rotary screw type air compressors are commonly used (67%). Energy saving between 18-27% is achievable by adoption of energy efficient PMSM invertor air compressors.
- About 55% of lamps being used in industry were of conventional inefficient types. There is a good scope to save energy by adoption of LED lamps/tubes.
- Adoption of BLDC fans will lead to an substantial energy saving.
- The presentation was followed by an interactive discussion with the unit representatives.