SHAKTI
SUSTAINABLE ENERGY
FOUNDATION

Confederation of Indian Industry

Energy Efficiency in Indian Railways

Best Practices Manual

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BEST PRACTICES MANUAL

(Pilot study in 6 Production units and 4 Workshops)

Indian Railways

Disclaimer

This manual is part of the Shakti Sustainable Energy Foundation(SSEF) and CII-Godrej GBC's effort to assist the Indian Railways achieve greater energy efficiency levels and to facilitate the designated consumers in Railways to meet their Perform, Achieve & Trade(PAT) targets set by Bureau of Energy Efficiency (BEE), Government of India.

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EXECUTIVE SUMMARY

Indian Railways is an Indian state-owned enterprise, owned and operated by the Government of India governed by the Ministry of Railways. It is one of the world's largest railway networks comprising 119,630 km of track over a route length of 66,687 km and 7,216 stations. It is an energy intensive organization which consumed over 18.2 billion units during 2015-16, contributing to 1.9% of the country's power generation for its traction and non-traction applications and the operational expenditure incurs about Rs.10,000 crore towards electricity charges. Indian Railways (IR) is an iconic organization in India, known for its large scale of operations, and reaching more citizens every day than any other organizations in the country. Due to the high energy consumption of the various Production Units and Workshops in the Indian Railways, the Bureau of Energy Efficiency, and Ministry of Power has identified Indian Railways as one of the designated consumer under the Perform Achieve and Trade (PAT) Scheme.

Confederation of Indian Industry (CII) is a non-government, not-for-profit, industry-led and industry-managed organization, playing a proactive role in India's development process. Founded in 1895, India's premier business association has over 7200 members, from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 100,000 enterprises from around 242 national and regional sectoral industry bodies. With 64 offices, including 9 Centre of Excellences, in India, and 7 overseas offices in Australia, China, Egypt, France, Singapore, UK, and USA, as well as institutional partnerships with 312 counterpart organizations in 106 countries, CII serves as a reference point for Indian Industry and the international business community.

CII- Sohrabji Godrej Green Business Centre (CII-Godrej GBC), one of the center of excellence of CII was established in the year 2004, as CII's Developmental Institute on Green Practices & Businesses, aimed at offering world class advisory services on conservation of natural resources. The advisory Services of CII -Godrej GBC include - Energy Management, Green Buildings, Renewable Energy, GHG Inventorization, and GreenCo certification, Green Product Certification, Waste Management and Cleaner Production Process.

Confederation of Indian Industry (CII) has signed a memorandum of understanding with the Indian Railways, to facilitate various energy and environment initiatives in the Indian Railways, on 26th July 2016, in the presence of the Ministry of Railways. The first project under this MoU, was conceived to support implementation of energy efficiency measures in selected Indian Railways units, 6 production units and 4 workshops.

With this as the background, this Best Practice Manual is developed to feature various technologies and best practices on Energy Efficiency front.. This manual is expected to assist Indian Railways production units to improve their energy efficiency levels and achieve the targets under PAT scheme.

However, implementation of these technologies calls for a sustained effort. Some of the technologies mentioned in this report are capital intensive and at times time consuming to implement. However, implementation of these projects can surely be beneficial to the units

INDIAN RAILWAYS INDUSTRY:

Indian Railways operates 13,313 passenger trains daily and in 2015-16, carried 8.107 billion passengers annually or more than 22 million passengers a day and 1.101 billion tons of freight annually across 29 states and three union territories. Railways is the most preferred form of long distance transport in most parts of the country.

The Indian Railways had a modest beginning in 1853, when the first train steamed off from Mumbai to Thane. In 1951, it was nationalized as a single unit, becoming one of the largest railway networks in the world. Indian Railways has over 53,101 Passenger Coaches, 2, 51,256 Freight Wagons and 11,122 Locomotives (Steam, Diesel and Electric) as per year 2015-2016 . It runs around 20,000 trains (both good and passenger) daily and has its own locomotive and coach production facilities.

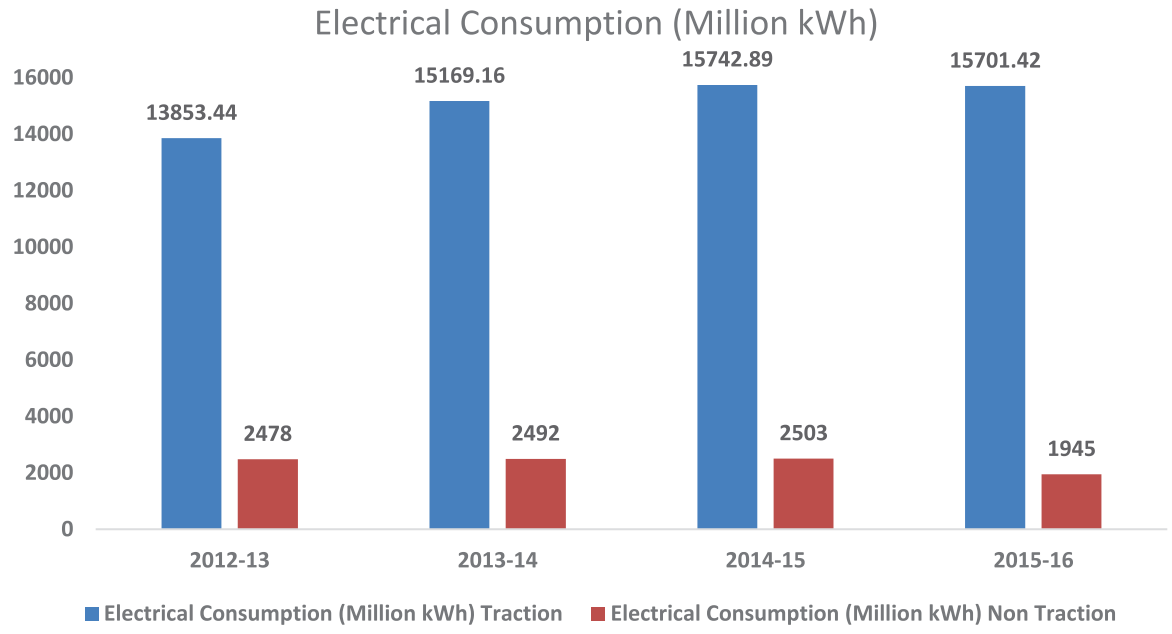
The Locomotives or Engines in India comprise of electric and diesel ones. Steam engines aren't used any longer, except in heritage trains. Engines are classified by their track gauge, power, model number and the work they are suitable for. Freight trains earn about 70% of the railway revenue. There are several passenger train services and are mostly classified by their average speed. A faster train has fewer stops than a slower one. Some of the faster trains are: Duronto Express, Rajdhani Express, Shatabdi Express, Garib Rath, Jan Shatabdi, Sampark Kranti Express, etc.

Many cities in the states all over the country have their own dedicated suburban networks to cater to commuters. Currently, suburban networks operate in Mumbai (Bombay), Chennai (Madras), Kolkata (Calcutta), Delhi, Hyderabad, Pune and Kochi.

Energy consumption in Indian Railways:

Indian Railways accounts for close to 1.9% of Country's total electricity consumption (IR utilized more than 18.2 billion kilowatt-hour (kWhr) electricity in 2015-16). Indian Railways has been taking steps towards enhancing energy efficiency and has been reducing its specific electricity consumption by about 3.0 % in traction on year to year basis, in both traction and non-traction areas.

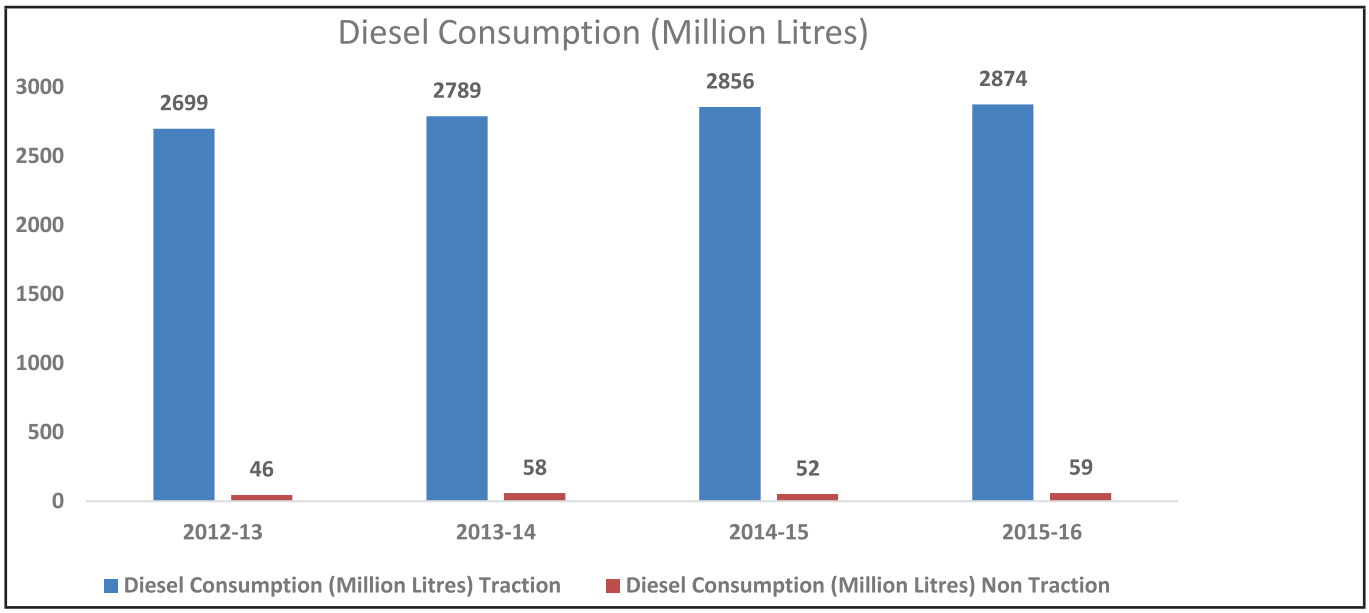
Fig 1: Electrical consumption of Indian Railways



Indian Railways has achieved 41% freight growth with only 20% extra energy. This is due to induction of energy efficient locomotives on IR, hence resulting improvement in SEC by 17.6%.

http://indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/IRSP_2015-16/Summary%20Sheet_Eng_pdf_pdf.pdf

Fig 2: Diesel consumption of Indian Railways[3]



Indian Railways consumes approximately 2.5 Billion Units of electricity for non-traction usage, investing about Rs. 1,700 crore per annum.

It can be inferred from the data that the energy consumption in non-traction category has almost been constant since last five years despite increase in the connected load due to number of energy conservation initiatives.

SOME OF THE CHALLENGES FACED BY INDIAN RAILWAYS

i. Turbulence of demand:

All the production units are designed for continuous operation. Batch operation of heavy machinery like arc furnaces not only consumes more energy but also reduces its life and efficiency. As the demand of the railway equipment like wheels, coaches, and locomotives is not continuous, it affects the effectiveness of plant machinery.

ii. Vintage of the Plants

Vintage of the plants has a key role in higher energy consumption of Indian Railways Production units. Many of the public sector units are old plants with vintage technologies. Introduction of new technologies in these plants proves to be very tedious thus hindering the progress of energy efficiency activities.

iii. Cost of energy efficiency

Any modification in the process for energy efficiency activities in Railway plants is capital intensive. Therefore, several plants are apprehensive to go ahead with energy efficiency activities. The industrial lending rates of the banks are very high in India and thus the Internal Rate of Return (IRR) is also high. This makes projects less attractive. In addition to this, there are no separate funds available for energy efficiency activities.

POLICIES FAVORING ENERGY ACTIVITIES:

Railways being the major consumer of energy, systematic programme were launched towards improving energy efficiency and energy conservation.

IR has been actively taking Policy initiatives by issuing various Guidelines/ Circulars on General Power Supply Systems like use of LED lights, Star rated equipment etc. Listed below are some of the recent major Policy Guidelines/ Circulars and manual issued for Energy Conservation and energy management in Indian Railways::

- Direction to take benefits of DELP scheme for LED bulbs for railway staff.
- Directions to carry out energy audit.
- Development and issue of Energy Audit Manual & Standard Template for Contract Procedure for Energy Audits Services for Indian Railways Installations by RDSO.
- Use of star labeled products on Railways: Indian Railways in the year 2007 has passed a notice to procure only star rated equipment (3-star or above) to which minimizes the use of energy.
- CRIS has also designed & developed IRGREENERI website to disseminate the information regarding green initiatives taken by Indian Railways which was launched by Minister of Railways. The website will act as a knowledge sharing platform on green initiatives and best practices.

ENVIRONMENTAL ISSUES FACED BY THE SECTOR

Indian Railways (IR) is the single largest carrier of freight and passengers in the country. It is a bulk carrier of several pollution intensive commodities like coal, iron ore, cement, fertilizers, petroleum etc. Being a major consumer of water and energy, policies adopted by the IR have a substantial impact on our environment and on the conservation of both water and energy in the country. Therefore, the approach of IR towards protection of the environment assumes great importance for tackling environment challenges.

Issues prevalent in the sector:

- Air pollution arises from the freight transportation

  Air pollution mainly arises due to handling of commodities like coal, iron ore, cement, fertilizer etc. at sidings/ goods sheds and transportation of these commodities in open wagons. These materials create serious air pollution when carried by rail in open wagons and during loading/unloading operation.

- Water management

  There is no proper system for monitoring the quality and quantum of waste water generated at the stations. Effluents are frequently discharged from major stations to the nearby low lying areas/water bodies and municipal discharge systems resulting in contamination of surrounding surface and ground water.

  Railway Board's instruction for installation of Effluent Treatment Plant at all major stations were also not adhered to.

- Waste

  Non segregation of degradable and non-degradable wastes, inadequate storage facilities and improper disposal of garbage are common at railway stations.

  IR transports about 14 Million of passengers every day and generates about 3980 MT of human wastes per day which is discharged directly on to the rail tracks. This pollutes the environment at both stations and alongside the tracks

❖ The sector is a major consumer of energy and as such is a major contributor to greenhouse gas emissions

Though many steps have been taken to reduce the pollutions like use of bio diesel and effluent treatments plants and bio toilets etc., compliance with the norms have not been followed in many places and the environmental concerns from Railways still persists.

PAT for Indian Railways

Perform, Achieve and Trade (PAT) is an innovative policy mandated, market based mechanism launched in 2012, designed to accelerate energy savings in energy intensive and large industries by incentivizing energy savings. Overachievement above the assigned targets will result in tradable ES Certs, whereas under-achievers have to comply by purchase of ES certs or by paying a penalty.

As per the schedule of the Energy Conservation (EC) Act, 2001, industries in 15 energy intensive sectors are being identified as a Designated Consumer (DC) and Railways are one of the identified energy intensive industries under the act notified them as a designated consumer. Indian Railways is divided into two categories i.e. Traction and Non Traction railways. All traction zonal railways having the annual energy consumption for traction of 70,000 metric tonne of oil equivalent (MTOE) per year and above are considered as DC and for non-traction system all production units having annual energy consumption 30,000 MTOE equivalent and above are considered as DC. In PAT cycle 2, 16 Zonal Railways and 6 production units are included.

The PAT targets for 6 productions are given below:

Production Units

Sl. No.	Name and Address of Dc	Registration Number	Baseline energy consumption norms and standards in kilogram of oil equivalent (kgoe) per unit of product) for the baseline year 2014-2015			Target 2018-19	Target,%
			Category	Kgoe/ Unit Produced	Unit Produced	Target Kgoe/Unit Produced	
1	Chittaranjan Locomotive Works, Chittaranjan	RLY0017WB	Locomotive	17328.85	260	16294.31	5.97
2	Diesel Locomotive Works, Varanasi	RLY0018UP	Locomotive	3421.05	266	3216.82	5.97
3	Diesel Loco Modernisation Works, Patiala	RLY0019PB	Locomotive (rebuilding and manufacturing)	3399.8	306	3196.84	5.97
4	Integral Coach Factory, Chennai	RLY0020TN	Coach	999.22	1704	939.57	5.97
5	Rail Wheel Factory, Bengaluru	RLY0021KA	Wheel	131.75	175175	123.89	5.97
6	Rail Coach Factory, Kapurthala	RLY0022PB	Coach (Equivalent)	1346.52	2042 (Equivalent)	1266.13	5.97

HOW TO USE THIS MANUAL

- The objective of this manual is to act as a catalyst to facilitate Indian Railways towards continuously improving the performance of production units and workshops, thereby achieving world class levels (with thrust on energy & environmental management). To set goals for improving the performance and move towards accomplishing the best standards, best practices adopted in similar industries have been included in this manual.
- The suggested best practices may be considered for implementation only after defining the application of the technology and fine tuning requirements of existing units.
- Suitable latest technologies may be considered for implementation in Indian Railways facilities to achieve world class energy efficiency standards. Assessment of feasibility of these technologies for individual plant conditions is also essential.
- The collated best operating parameters and the best practices identified from various plants need not necessarily be the ultimate solution. It is also possible to achieve better standards and establish benchmark standards in operation and maintenance practices.

The technologies proposed in the manual is outlined based on potential identified from the numerous visits conducted to selected facilities of Indian Railways, as follow:

1. Diesel Locomotive Works (DLW), Varanasi, UP.
2. Chittaranjan Locomotive Works (CLW), Chittaranjan, West Bengal.
3. Integral Coach Factory (ICF), Perambur, Chennai, Tamil Nadu.
4. Rail Coach Factory (RCF), Kapurthala, Punjab.
5. Diesel Loco Modernization Works (DMW), Patiala, Punjab.
6. Rail Wheel Factory (RWF), Bangalore, Karnataka.
7. Locomotive Workshop, Jamalpur, Bihar
8. Wagon Repair Workshop, Jhansi, UP
9. Golden Rock Railway Workshop, Trichy, Tami Nadu
10. Carriage & Wagon Workshop, Jagadhri, Haryana

The manual also illustrates sample calculations to assess the cost benefits of implementing a technology at an individual facility and the potential for replication across other Indian Railways facilities.

Therefore, the Indian Railways team will find this manual resourceful to improve the performance and achieve world class energy efficiency standards.

ELECTRICAL DISTRIBUTION & LIGHTING

1. Improving power factor close to unity

Project Background:

During the site visit to various production units of Indian Railways, it was observed that average power factor maintained by the units was 0.96, thereby drawing high current for the equivalent apparent power consumed by the utilities. Therefore, it is essential to improve the power factor to 0.99 to minimize the losses due to transmission and switch gear equipment.

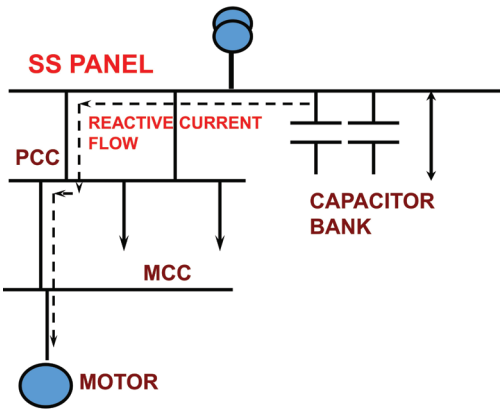
There exists various losses due to maintenance of low power factor, as follows:

- Due to low power factor, the current drawn by the equipment is higher for the equivalent apparent power of the equipment, thereby increasing the copper losses in the conductors and switch gear machinery.
- Low power factor results in voltage drop across alternators, transformers, transmission lines, etc., therefore requiring additional equipment to compensate for the loss in voltage and maintain the desired power quality which increases the cost of the power systems.
- At low power factor, transmission or distribution of power at a constant voltage draws more current, hence, increasing the size of transmission lines.

Project Description:

Power factor can be improved by installing Automatic Power Factor Correction (APFC) equipment. The best method to improve the overall power factor of the facility is by using distributed Reactive Power compensation.

The figure shown below illustrates the distributed power factor compensation method in which capacitor banks are installed at PCC level as well as at the MCC level which improves the power factor on the load side as well as on the distribution side.



Installation of APFC increases the power factor, thereby resulting in the following benefits:

- Minimum voltage drop at distribution side.
- Low distribution losses.
- Copper loss in the transformer reduces.
- Maximum demand decreases for the same load which helps in addition of extra loads in the transformer in case of expansion.

Cost Benefit Analysis:

The sample calculation of cost benefit analysis for one Indian Railway facility, by improving power factor is shown below:

Description	Value	Unit
Present average Power factor	0.96	
Proposed average Power factor	0.99	
Average monthly Unit consumption	2322114.58	kVAh

Average monthly Unit consumption after Improved Power factor	2251747.47	kVAh
Average Monthly Energy Saving	70367.10	kVAh
Unit cost	6.35	Rs./kVAh
Annual Savings	53.61	Rs. Lakhs
APFC Requirement	464.42	kVAr
APFC Requirement (50 kVAr x 10 Nos.)	500	kVAr
Total Investment	9	Rs. Lakhs
Payback	2	Months

Replication potential:

This proposal has a replication potential in 5 units out of 10 Indian Railways facilities and can be implemented whose power factor is low.

Benefits:

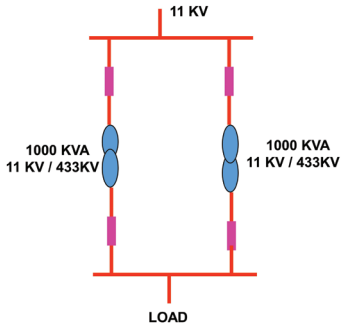
By improving the power factor to 0.99, cost savings potential of Rs. 330 Lakhs can be achieved. The investment incurred by implementation of this proposal is Rs. 57 Lakhs, with a payback of 2 Months.

2. Isolating primary of idle running distribution transformer

Project Background:

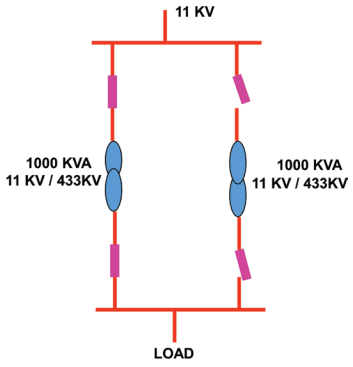
Distribution transformers are used to step down the voltage form the main receiving station to various utilities. As a general practice, the primary of the distribution transformer is charged to have backup power supply, although no load is connected to the transformer.

The loss arises due to the inherent magnetization of the transformer, thereby consuming power. This loss is referred to as no-load loss of the transformer. The no-load losses is a factor which is proportional to the rating of the transformer.



Project Description:

It is advised to isolate the primary of idle transformer in order to avoid the no-load losses, thereby saving energy consumed during idle condition of the transformer.



Cost Benefit Analysis:

The sample cost benefit analysis of the isolating the idle transformer is shown below.

In one Indian Railways facility, there are 5 transformers in idle condition, namely, 1 x 8 MVA and 4 x 1000 kVA

Isolate Primary of the idle distribution transformer		
Description	**Value**	**Unit**
Total No of TF	26	
No of TF in Idle condition	5	
No-load losses	11.8	kW
Total Losses	11.8	kW
Operating Hours	8760	Hrs.
Annual Savings	7.26	Rs. Lakhs

Replication Potential:

This replication potential of this nil-investment proposal is in 5 units out of 10 Indian Railways facilities and corresponding savings can be achieved.

Benefits:

By isolating the primary of idle distribution transformers, savings potential of Rs. 46 Lakhs can be achieved without any investment.

3. Installation of Light pipe to harness day light

Project Background:

Lighting system finds application in office spaces and shop floors of the workshops and contributes to a significant amount of energy and cost for electricity for lighting load. For instance, one of the production unit of Indian Railways utilizes artificial lighting at various locations of the plant, which can be substituted with day lighting.

Latest advancements in technology allows us to tap the incident solar light which can be considered as a viable alternative to conventional lighting methods.

Project Description:

Light pipes are primarily used for illuminating deep interior spaces where windows do not have provision for illuminating indoor environment. Light pipe consists of mainly three parts (collector, transmission pipe, and diffuser).

- Collector comprises of a Dome which functions to collect sunlight from all angles and transmitting maximum possible sunlight into the tube. Generally Polycarbonate or Acrylic materials are used for the Domes.
- Light is then refracted through the collector and transmitted into the tube. Reflective material such as anodized aluminum with silver coating are used on the inner surface of the tube.
- Diffuser plate is placed at the other end of the tube, which functions to evenly distribute light inside the room

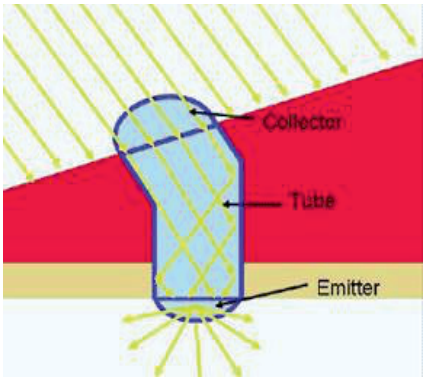


Figure 4 Parts of Light pipe

Both direct and diffuse radiation falling on receiving end of the pipe can be channeled, after multiple reflections off the inner walls, and used at the exit. The inner surface of the light pipes are made with a material having high spectral reflectivity for all angle of incidences and all wavelengths of considered spectrum width. Any variation in spectral reflectivity of pipe surface leads to change in spectral distribution of transmitted radiation.

In the areas where roof mounting is not feasible due to practical considerations, wall mounting of light pipes can also be done.

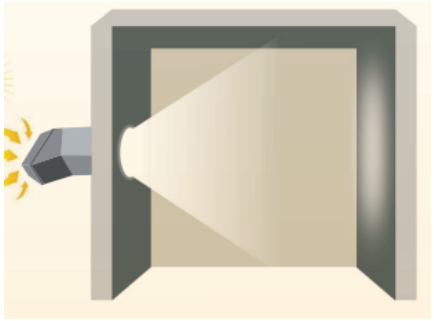


Figure 5 Wall mounting of Light pipe

Despite the advantages of the technology, there exists barriers in implementation of light pipe, namely:

- For mass replacement, disposal of conventional lights is difficult
- While installing the light pipes in dusty areas care should be taken care to clean the dome in a timely manner

Cost Benefit Analysis:

The following are the Lighting load and Lux levels in various locations of the railway unit.

Description	STL(40W)	T5(28W)	LUX	Total load (W)
Generator office	2	2	124	136
Stores	12	1	106	508
Computer room	4	0	134	160
Inverter section	16	8	217	864
Pump section	16	8	124	864
Total	50	19	705	2532

It is recommended to install 5 light pipes in the identified area and switch off the discharge lamps during the day time. This will help in maintaining good level of illumination during the day time without electrical energy.

Description	Value	Unit
No of light pipes to be installed	5	
Total lighting load	2.1	kW
Annual lighting energy saved	7350	kWh
Monetary savings	0.47	Rs. Lakhs
Investment	1	Rs. Lakhs
Payback	26	Months

Replication Potential:

This proposal can be replicated in all the 10 IR facilities and corresponding savings can be achieved.

Benefits:

Implementation of Light pipes (at least 10 nos.) can result in annual cost savings potential of Rs. 9 Lakhs with an investment of Rs. 20 Lakh, and an average payback period of 28 months

4. Replacement of old welding sets with new Inverter-based welding technology

Project Background:

Welding is a critical operation in the Indian Railways in locomotive manufacturing units, coach manufacturing facilities and workshops. During welding operation, an electric arc is formed between the consumable wire electrode and the work piece where the heat generated causing the work piece to melt and join together.

Specific application requires specific welding technique such as Metal Inert Gas (MIG), Gas Metal Arc Welding (GMAW), etc. This technique uses a spool of wire to feed towards the workpiece and also consists of inert gas that flows from the machine to the welding handle to isolate the weld from the surrounding air.

The process of the thyristor based welding technology is shown below:

In thyristor based welding machine, significant part of the power consumption goes into heating the transformer and the surrounding air, resulting in significant losses.

Project Description:

The present scenario of thyristor based welding technology consumes significantly high energy compared to energy efficient inverter based welding equipment.

In inverter based technology, the 50 Hz incoming power is fed directly into a transformer, which is rectified to 50 Hz DC. Then it is fed into the inverter section of the power supply where it is switched on and off by solid state switches at frequencies as high as 20 kHz. This pulsed, high voltage, high frequency DC is then fed to the main power transformer, where it is stepped down to low voltage 20 Hz DC suitable for welding and is processed through a filtering and rectifying circuit. Output control is performed by solid state controls which modulate the switching rate of the switching transistors.

The operation of the inverter based welding technology is illustrated below:

Cost Benefit Analysis:

Rated capacity of the welding equipment	:	400A/30V
Output parameters	:	30 A - 250 A, 4.3 KW
Length of rod considered	:	2.5 mm
Number of thyristor based welding sets	:	100
Daily Operating hours	:	2 hrs
Idle time	:	30 mins
Shifts	:	2 hrs

Description	Inverter	Thyristor	Unit
Power factor	0.7	0.9	
Input power taken during operation	10.56	8.33	kW
Input power taken during no load	0.5	0.13	kW
Power consumption per day	42.74	33.45	kWh
Annual Savings	14.50		Rs. Lakhs
Investment required	40.0		Rs. Lakhs
Simple payback period	34		Months

Replication Potential:

This proposal can be replicated in 9 units out of 10 IR facilities and corresponding savings can be achieved.

Benefits:

Considering replacement of 100 nos. of thyristor based welding sets in a phased manner, can result in annual cost savings potential of Rs. 130 Lakhs (conservatively) with an investment of Rs. 360 Lakh, and an average payback period of 33 months

5. Regenerative drives for EOT Cranes application

Project Background:

Cranes find much application in Production units and workshops for material handling. The selection of cranes is a dependent factor on the application of load, capacity and time of operation

Cranes consume a significant amount of energy to transfer loads from one place to another pertaining to three axes of motion, namely, Hoist, Travel and Cross Travel.

During lifting operation, the motor draws current from the main incomer, thereby generating the required torque to lift the component. While lowering, the self-weight of the component, accompanied with dynamic braking is used to provide precise control of operation to lower the component at the required destination. During this operation, the shaft of the motor rotates in the opposite direction, wherein the energy is dissipated in the form of heat through the resistors in the braking unit.

The figure illustrates the dynamic braking operation of the cranes utilized in the workshops of Indian Railways, which indicates a significant potential for Energy Efficiency Measures.

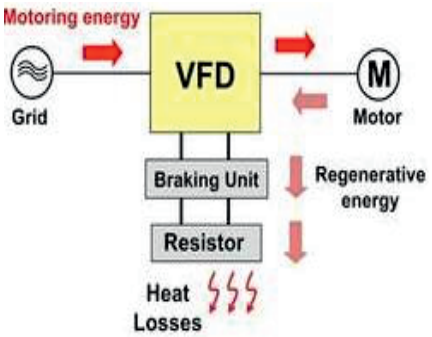


Figure 6 Block diagram of dynamic braking in OH cranes

Project Description:

As illustrated in the figure, the heat dissipated during the lowering operation of the crane, can be converted into useful energy by installation of a Regenerative Drive.

During lowering operation, the weight of the load automatically rotates the motor, thereby, acting as generator and produces electrical energy. This electrical energy which initially dissipated as heat energy, can be converted into useful electrical energy and fed back to the supply unit, using regenerative drives.

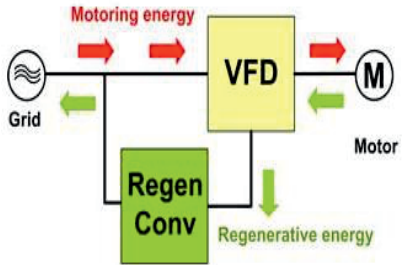


Figure 7 Block diagram of regenerative braking in OH cranes

There exists various barriers in implementing of regenerative drives:

- The energy saving is dependent on the operation time (running hours) of the crane. This method is most suitable for continuous crane use applications.
- Initial cost may be high.

Cost Benefit Analysis:

The sample calculation of cost benefit analysis of implementation of Regenerative drive for one crane is shown below:

- Working Load : 20 Ton
- Main hoist motor rating : 45 kW
- Present dynamic braking resistor values : 2 x 17.5 kW

Under regenerative braking we can save regenerative energy which is been currently wasted as heat at dynamic braking resistors.

- Regenerative unit capacity selected : 37 kW

This analysis considers 30 mins of hoist operation per hour of continuous operation as the operational time of the hoist.

Description	Value	Unit
Input power of the hoist motor	45	kW
% of regeneration (conservative)	45	%
Hoist operating hours per day	4	Hrs.
Operating hours during motoring mode	2	Hrs.
Operating hours during regenerative mode	2	Hrs.
No. of working days	350	Days
Annual Operating hours	1400	Hrs.
Energy saved	14175	kWh
Annual monetary savings	0.92	Rs. Lakhs
Investment required	2.5	Rs. Lakhs
Simple payback period	33	Months

Replication Potential:

Although the investment of regenerative drives is relatively high, the proposal can be replicated in 9 out of 10 IR facilities, which utilizes continuous operation of cranes.

Benefits:

By installing regenerative drives, the following benefits can be achieved:

- Conservatively at least 45% of hoist energy supplied to main feeder, thereby reducing the power consumed from the grid.
- Energy savings can be monitored with a digital HMI panel.

Implementation of regenerative drives for hoist motors in 20 Ton cranes, considering 30 Nos. for production units and 20 Nos. for workshops, results in a cost saving potential of Rs.200Lakhs, incurring an investment of Rs500Lakhs, with a payback of 30 Months.

6. Replacement of Ceiling Fans with Energy Efficient BLDC fans

Project Background:

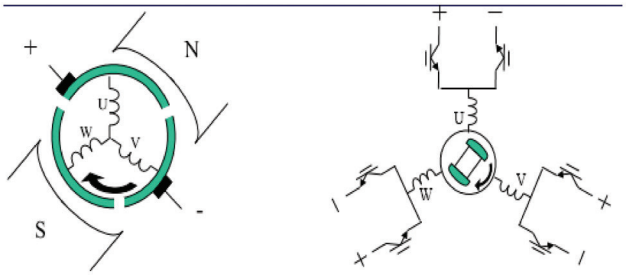
Conventional ceiling fans operates using an induction motor which comprises of a stator and a rotor that are responsible for rotating motion.

An induction fan consists of coils (also known as windings) on Stator and Rotor, which induces anelectric flux when current passes through the stator winding. This current flows through the coil depending on the stator arrangement. The conduction of current through the coils in rotor causes the motor to rotate.

Regulation of speed in an induction fan is either through resistance based or voltage chopping mechanisms, resulting in significant amount of energy lost as heat, albeit the average consumption of conventional ceiling fan being 70 W.

Project Description:

A BLDC fan works with BLDC motor instead of a conventional induction motor consumes as low as 28W on an average, which is significantly less when compared to the conventional ceiling fan.



The primary difference between BLDC and ordinary DC fans is the commutation method which is the technique of changing the direction of current in the motor for the rotational movement. In a BLDC motor, in the absence of brushes, the commutation is done by the driving algorithm in the electronics. The main advantage is that over a period of time, due to mechanical contact in a brushed motor the commutators tend to wear and tear, which is eliminated in BLDC Motor thereby improving the durability of the motor.

The key challenge of the technology is the higher investment incurred compared to the conventional ceiling fans, resulting in longer payback periods.

Replication Potential:

This proposal can be implemented in all the 10 IR facilities which uses conventional induction based fans in office space and shop floors of the workshop.

Speed	Power consumption in Watts	
	Ordinary Fan	Super fan*
Low	12	4
Medium	39	14
High	75	35

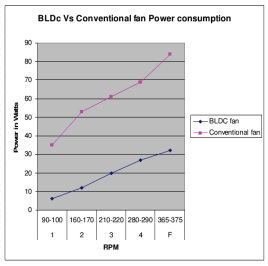


Figure 9 Power consumption comparison

Benefits:

Replacing conventional ceiling fans with Energy Efficient BLDC fans can reap the following benefits:

Nearly 50% of the energy savings can be obtained.

Due to negligible heating of the motor, the life of a BLDC fan is also expected to be much higher than ordinary fans.

Considering replacement of 500 fans in production units and 300 fans in workshops on average, including colony area, the cost savings potential of Rs. 80 Lakhs can be achieved with an investment of Rs. 210Lakhs, at a payback period of 32 months.

7. Installation of Energy management system to optimize energy consumption

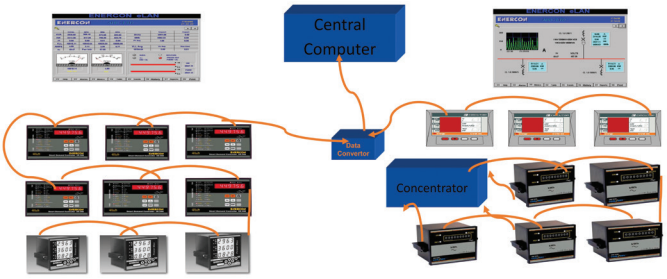
Project Background:

The energy meters are installed in the plant at the substation and main incoming feeder of the facility.This is essential to analyze the trend of operation, so as to draw conclusions on the performance assessment of the equipment.

In most of the production units and workshop of the Indian Railways, unavailability of monitoring equipment to assess energy performance results in wastage of energy at the end-user.

Project Description:

Energy management provides the means to controlling and reducing the energy consumption. It involves metering, data collection, data analysis and interpretation of energy consumption.



EMS communicates with multiple energy meters installed at site location of the utility. Energy monitoring system can detect overloading from a section and enable control measures to act against it.

Implementation of Energy Management System provides the following benefits:

- Identification and assessment of application and consumption and prioritizing in those areas identified as high consumers.
- Identification and prioritization of savings opportunities by comparison of economic variables such as initial investment required and the payback period.
- Defining the baseline energy consumption by comparingthe energy performance of the industry before and after initiating the energy management system.
- Analyzing the trend of energy consumption using the system data and, analyzethe performance of the organization inachieving the energy objectives and also establish future energy goals and programs.

Benefits:

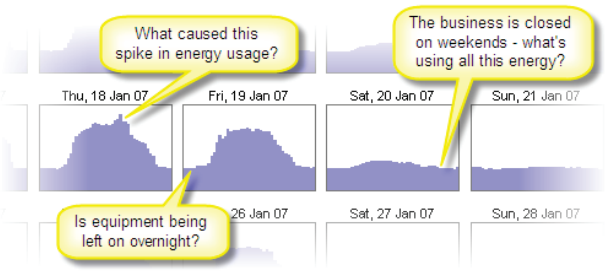


Figure 11 some possible references from EMS data

On a conservative basis, 1% of the energy consumed by the plant can be saved by installing Energy Management System.

By installation of Energy Management System in 10 workshop/production units, cost savings potential of Rs. 200Lakhs can be achieved with an investment of Rs. 120Lakhsat an average payback period of 8months.

8. A. Replacement of old reciprocating compressors with screw compressors

Project Background:

Generally, the compressor performance is constant over a period of 4 to 5 years of its operation. Also, with regular and proper maintenance and overhauling, the compressor performance deteriorates, especially in the case of reciprocating compressor, where components such as cylinder bore, piston, valves and other accessories are rigorously maintained.

Performance assessment of a compressor can be carried out by evaluating the free air delivered by the compressor and measuring the power consumed by the compressor. The specific energy consumption (SEC) of the compressor can be estimated and compared with other operating compressors.

The average operating SEC of the reciprocating compressor is 0.18 kW/CFM (@ average operating pressure of 5.5 bar). The performance deteriorates due to various factors such as aging, maintenance, and other operating conditions with which the compressor is operating.

Project Description:

Screw compressors operate at an average SEC of 0.15 kW/CFM (@ average operating pressure of 5.5 bar), therefore reducing the power consumption of the screw compressor for the same capacity as a reciprocating compressor. The screw compressor offers reliability at the required loads and can also be integrated with a VFD to cater variable loads requirements.

In addition, the screw compressor offers the advantage of lesser maintenance costs than the reciprocating compressors.

Cost Benefit Analysis:

The sample cost benefit analysis of replacement of existing reciprocating compressor with screw compressor is shown below:

Description	Value	Unit
Number of reciprocating compressors	7	
Average operating SEC of reciprocating compressors	0.18	kW//CFM
Average operating SEC of screw compressors	0.15	kW//CFM
Compressed air requirement	7000	CFM
Energy Saving potential	210	kW
Annual Operating hours	2400	Hrs
Cost Savings	32	Rs. Lakhs
Investment	78.4	Rs. Lakhs
Payback Period	30	Months

8. B. Installation of VFD for existing screw compressors

Project Background:

The traditional way of exercising control over a compressor is by operating the motor at full speed till the compressed air attains the required pressureand then operating the motor at idle mode. The compressed air stored in a reservoir (or) receiving tank at a pressure higher than the required pressure to allow a hysteresis in the pressure.

This "load-unload" method is a common but not a recommended practice, since the motor runs continuously at its nominal speed regardless of the work done by the compressor.However, when the required pressure for the compressed air is attained, a device known as a slide valve is activated, which disconnects the compressor from the driver. This device uncovers part of the rotor and proportionately reduces capacity of the machine down to typically 25% of the compressors capability, thereby unloading the compressor.

Project Description:

Energy can be saved by using a VFD where the motor draws power considering a set point lower than the previously set average pressure. VFD is power electronics based device which converts the base fixed frequency, fixed voltage to a variable frequency, variable output voltage thereby providing precise control on the speed of the induction motor.

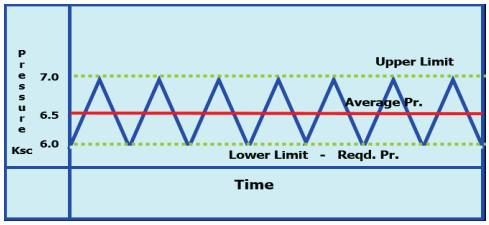


Figure 12 Compressor pressure graph before VFD

For instance, in case of a screw compressor, at Loading & Unloading pressure of 6 bar and 7 bar respectively, the average pressure at which the compressor operates is 6.5 bar, can be considered as a reference value.

By installing a VFD, the average operating pressure can be reduced to 6.1 bar. Hence, there is a significant savings in the compressor energy consumption due to reduction in the operating pressure.

The operating pressure pattern of the compressor is illustrated in the figure

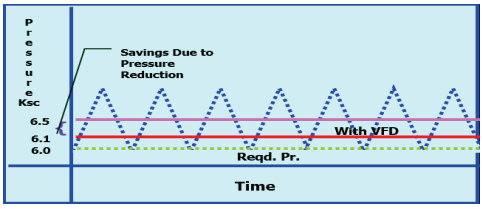


Figure 13 Compressor pressure graph after VFD

Replication potential:

This proposal can be implemented in a phased manner in all the 10 production units/workshops of the Indian Railways.

Benefits:

Replacement of old reciprocating compressors with energy efficient screw compressors yields the following benefits:

- Increased reliability due to reduced shutdown and maintenance of reciprocating compressors.
- The maintenance downtime of screw compressors are relatively lower resulting in reduced operational costs.

Implementation of VFD in compressors results in the following benefits:

- As the operating pressure is reduced, compressor power consumption is reduced which is proportional to the operating pressure.
- Increased reliability of the compressors, ensuring consistency of operation.

Implementation of this proposal achieves a cost saving potential of Rs. 160 Lakhs, incurring an investment of Rs. 520 Lakhs with a payback period of 38 months.

9. Intelligent Flow Controller for compressed air network

Project Background:

The quantity of compressed air requirement varies depending on the users. The variation in quantity is substantial due to sudden requirement in the intermittent users. The duration of usage may be minimal but quantity requirement remains significant. This leads to fluctuation in overall system pressure.

A sudden air demand leads to reduction in overall system pressure and the compressor goes into loading mode. There exists a time delay between reduction in system demand and the compressor to sense the pressure to run at load mode. Often, the time delay is so much that by the time the compressor loads, the demand is inexistent and the compressor pumps air into the system to the higher pressure limit.

Thus the system operates for artificial demand and not for the real demand which consumes unnecessary power.

Project Description:

An intermediate controller creates a useful storage by introducing a controlled differential pressure across an upstream receiver. This storage isolates the compressor from demand side. Peaks are dealt with the reserve energy stored.

Thus by providing air at controlled differential at optimum pressure, mass of air is reduced and high pressure storage is created to increase the unload time of compressors. The increase in unload time leads to reduction in overall energy consumption of compressors.

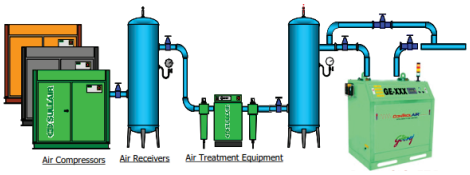


Figure 14 System of compressors with intelligent flow controller

The intermediate controller is located at the intermediate point of the system. This is downstream of the filtration and drying equipment (supply side) and upstream of the main piping distribution system (demand side)

Cost analysis:

A sample cost benefit analysis of implementation of the intelligent flow controller is shown below:

No. of operating compressors	:	4
Type	:	Screw
Motor rating	:	150 kW
Rated CFM	:	1000 CFM

Description	Value	Unit
Energy consumption of compressors	600	kW
% savings achieved	5	%
Energy saving potential	30	kW
Annual Operating hours	2400	hrs
Annual units saved	72000	kWh
Annual Savings	4.5	Rs. Lakhs
Investment required	10	Rs. Lakhs
Simple payback period	27	Months

Replication Potential:

The proposal can be implemented in all the production units and the workshops where the demand side management of the compressors is essential in compressor operation.

Benefits:

Implementation of the Intelligent Flow Controller yields the following benefits.

- Users are isolated from the compressor.
- Any fluctuation on the demand side is dealt with the reserve which reduces unnecessary loading of compressor and saves energy

By implementing the proposal, 5% energy savings can be obtained in compressed air network, resultingin savings potential of Rs. 100 Lakhs, incurring an investment of Rs. 125 Lakhs, with a payback period of 27 months.

10. Transvector nozzle for compressed air cleaning application

Project Background:

Utilization of compressed air for servicing application such as cleaning and drying is a common but not recommended practice for such applications. The service air points are being used at a pressure of 5.5 kg/cm2, resulting in wastage of energy. This indicates the potential for energy saving

For instance, using cleaning air from a hose of ½" dia., at 5.5 kg/cm2, the amount of air consumed is approximately 336 cfm.

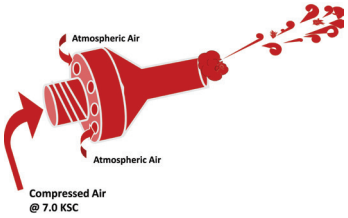
For cleaning applications, the volume of airflow is the governing factor and not the operating pressure of the compressed air. Therefore, cleaning can be effectively achieved with a low pressure compressed air as well, thereby saving significant amount of energy.

As per the standards, reduction in the delivery pressure by 1 bar in a compressor would reduce the power consumption by 6 – 10 %. As the compressor is operated a higher pressure than is required, there is a scope of saving energy.

Project Description:

It is recommended to utilize a dedicated compressor at low pressure for service air applications. In order to further optimize the compressed air intake, transvector nozzles can be utilized for cleaning applications

When compressed air enters the nozzle or jet, it fills a chamber with only one exit path - a thin annular orifice. As air passes through this orifice, the venturi effect of the orifice entrains the free surrounding air as it exits. This results inincreased airflow volume more than supplied by the compressed air.



Hence the required volume and pressure required for cleaning application is met by consuming minimum amount of compressed air. Results indicate that almost30 to 40 % of the atmospheric air is utilized, thereby reducing the compressed air consumption.It indirectly saves load on the compressor and saves the energy consumed by the compressor.

Figure 15 Transvector nozzle operation diagram

Cost Benefit Analysis:

The sample cost benefit calculation of the energy savings by implementing transvector nozzle is shown below:

Description	Value	Unit
Number of cleaning points considered	30	
Flow through 1/2 inch hose at 5.5 bar pressure (as per standard)	152	CFM
Savings in cfm consumption with transvector nozzle	60.8	CFM
Present SEC (Average)	0.15	kW/CFM
Total savings	136.8	kW
Average Annual Operating hours	100	Hours
Unit cost	6.35	Rs./kVAh
Annual savings	0.86	Rs. Lakhs
Investment required	0.60	Rs. Lakhs
Payback period	9	Months

Replication Potential:

Application of service air is common in all the 10 Indian Railways facilities and implementation of transvector nozzle can be replicated in all the production units and workshops.

Benefits:

- Implementing transvector nozzle indirectly saves load on the compressor and saves the energy consumed by the compressor.
- By using transvector nozzle, around 40% of the compressed air usage can be reduced.

By replacing 30 nozzles, cost saving potential of Rs. 10 lakhs can be achieved with an investment of Rs. 8 Lakhwith a payback period of 10 months.

11. Installation of Level Sensor based auto drain valves

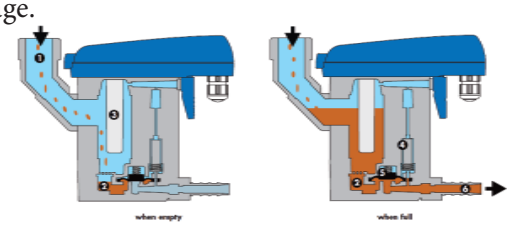
Present scenario:

The drain valves installed in the plant are timer based drain valves. In a timer based drain valve the condensate drain has to be changed based on atmospheric conditions. Another disadvantage is compressed air loss of some quantity cannot be avoided as the timer setting has to be set a higher value to ensure loss of condensate. If the timer is set at a lower time setting, the compressed air drain are manually opened to allow water collected. Some amount of compressed air loss cannot be avoided by using timer based drain valves.

An alternate to timer based drain valves is sensor based drain valves, which senses the level of condensate collected and drains only the condensate avoiding compressed air loss. There is a good potential to replace timer based drain valves with level based drain valves, which avoids compressed air leakage.

Project Description:

Level based drain valves work by sensing the level of condensate accumulated in the drain. The below mentioned figure describes the working of a level based drain valve.



The condensate flows through the inlet valve and is collected in the housing. The capacitive sensor senses the quantity of condensate in the drain and gives a feedback to the electronic sensor based on the filling level. When the level of condensate is full in the housing the pilot valve is activated and the membrane opens the outlet causing the condensate to be removed. Once the condensate level drops the pilot valve closes the membrane, thus avoiding loss of any compressed air in the system.

The drain valve at the receiver is currently leaking compressed air and this can be avoided by installing a level based drain valve

1 - Inlet 2 - Housing 3 - Capacitive sensor 4 - Pilot valve 5 - Membrane 6 - Outlet

Cost Benefit Analysis:

The sample calculation of cost benefit analysis of modifying the drain valve is shown below:

Description	Value	Unit
Capacity	4000	CFM
CFM saved by auto drain valves	80	CFM
Power saved by auto drain valves	12	kW
Annual Operating hours	800	hrs
Annual savings	0.60	Rs. Lakhs
Investment	0.80	Rs. Lakhs
Simple Payback Period	16	Months

Benefits:

- 2% reduction in compressed air leakage
- Automatic draining of condensate which reduces leakge and cleaning involved

By installing auto drain valves in Indian Railways 6 production units and 4 workshops, cost savings potential of Rs10Lakhs can be achieved with an investment of Rs. 11 Lakhs and a payback period of 14 months.

12. Opportunity to reduce compressed air leakage

Project Background:

Leakages is considered to be one of the significant source of wasted energy in an industrial compressed air system, which contributes up to wasting 20-30% of a compressor's output.

In addition to the wasted energy, leaks can also contribute to other operating losses. Leaks cause a drop in system pressure, which can make air tools function less efficiently, adversely affecting production. Leakages also forces the equipment to run more number of cycles, which is detrimental to the life of compressors.

Project Description:

The first step of the arresting the leakage is to quantify the percentage of compressed air which is leaked to the surroundings. It is essential to ensure that there is no demand for compressed air in the system while conducting the leakage test,and all user points remain closed. The following are the steps to be followed for conducting a leakage test:

- Start the compressor and allow it to run
- If there are no leakages, the compressor once unloaded should not load again as there is no consumption at the user point
- If there are leakages, it will operate in load and unload mode
- Note down the loading and unloading time of the compressor. The percentage loading indicates the percentage leakage.

Total leakage percentage can be calculated as

Leakage (%) = {UL/(UL+L)}*100

(UL= Unload time; L= Load time)

Figure 16 Red tag to air leakage point

The percentage leakage should be less than 10% of the total capacity of the compressor.

Red tag system - A leak prevention program:

In order to prevent leakages in the system, a red tag system is adopted and the following steps are carried out:

- Form a team among the employees with an objective to arrest leakages and handover red tags to each one of them
- Ensure that all the compressed line is distributed among employees
- Using an ultrasonic detector, identify the leaks in the compressed pipe line and at the user points, or notice for a hissing sound, and place a red tag at the identified leak
- Rank the leak based on its severity (on a scale of 10)

- Instruct the maintenance team to arrest the leaks and remove the red tag once the leak is arrested. When there is no red tag in the system, it can be concluded that the leaks are at minimum in the system.

Cost Benefit Analysis:

Air leakages of compressed air should be limited to 10% of compressed air delivered.

Anticipated savings obtained by arresting leakages in compressor:

Description	Value	Unit
Present leakages	30	%
Desirable leakages	10	%
Power drawn per CFM	0.16	kW/CFM
Reduction in leakages (from 48% to 15%)	200	CFM
Power saved by arresting leakages	33	kW
Annual operating hours	2400	Hrs.
Annual cost savings	5.02	Rs. Lakhs
Simple Payback Period	Immediate	

Replication Potential:

The red tag system must be adopted in all the10 IR units where compressed air is a significant consumer of energy and leakages must be arrested to less than 10% or lower.

Benefits:

By arresting the air leakages by 20% by adopting red tag system, cost saving potential of Rs. 50 Lakhs can be achieved with negligible investment and almost immediate payback period.

13. Aluminum piping for compressed air network

Project Background:

Compressed air piping is the key factor which governs the flow, pressure and efficiency of the compressed air system in a plant.

More than 60-70% of all compressed air systems installed today use black iron or galvanized pipe, due to a variety of factors:

- Contractors are familiar with these materials.
- Material costs are low.
- The pipe and compressed air system fittings are readily available.
- Steel pipe is rated for high pressure

Steel pipes shows greater tendency towards corrosion in the presence of moisture. The rough surface of the pipe creates more turbulence, resulting in pressure drops across the end user.

In various production units and workshops of Indian Railways, it has been observed that the pipe line network of the compressed air system is as long as 10-15 kms. At such magnitude, various contaminants, turbulent flow, and the material used impact the air quality and the energy consumed by the compressor.

Project Description:

Aluminum piping is superior metal compared to the conventional steel piping for the following reasons:

1. Lower installation costs.
2. Easier to install and to modify.
3. Much lighter in weight.
4. Better resistance to corrosion
5. Secure fitting and less leakages.

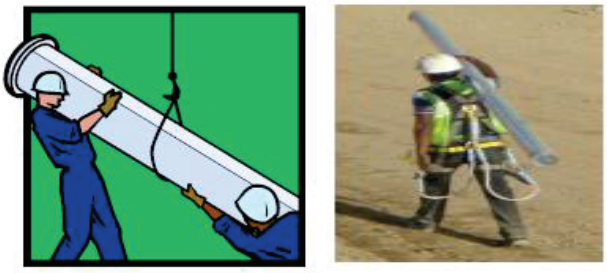


Figure 17 Weight of steel vs Al pipe

The following table provides a brief comparison of various materials utilized for compressor air network:

Description	Carbon Steel Pipe	Stainless Steel Pipe	Aluminium Pipe	Remarks
Insulation Time	Slow	Slow	Quick	No. Weldin,0ver 50% quicker
Modification	Hard	Hard	Easy	Quick to install
Modification Time	Long	Long	Short	Add a compressed air branch with 10min
Inner Roughness	1.8mm	1mm	0.2 -0.4mm (N4)	Extruded formation, smooth inner
Pressure Leakage	Bigger	Big	Small	Low roughness, small pressure drop
Leakage	10%-30%	5%-10%	0%	O seal ring
Corrosion After long time	Terrible	Few	No	Inner wall without chromium anti-corrosive treatment
Impact on air quality	Big	Small	No	No harm to the air equipment
Initial investment	Low	High	High	
Running Fee	Very High	High	Low	

The physical illustration of the MS pipes and the Aluminum is shown below:

Figure 18 Corrosion in steel vs Al pipe

Cost Benefit Analysis:

The sample calculation of cost benefit analysis of implementing aluminum piping is shown below:

Description	Value	Unit
No of operating screw compressors	4	
Capacity	4000	CFM
Average Power Consumption	600	kW
Average Power saving on conservative basis	30	kW
Annual operating hours	2400	Hrs.
Annual cost savings	4.5	Rs. Lakhs
Investment	18	Rs. Lakhs
Simple Payback Period	48	Months

Replication Potential:

The proposal can be implemented in 8 IR facilities out of 10,which uses MS piping network for compressed air network.

Benefits:

Replacing the steel pipes with Aluminum piping yields the following benefits:

- 5% energy savings can be achieved
- Zero leakage
- Less friction
- Improved air quality
- Lighter weight & ease of installation

By implementing the proposal, 5% energy savings can be obtained in compressed air network, resulting in savings potential of Rs. 37 Lakhs, incurring an investment of Rs. 132 Lakhs, with a payback period of 43 months.

14. Energy Saver for packed Air Conditioning units

Project Background:

In Administrative building of production units & workshops Split/Window AC units and packaged AC units are installed to cater the HVAC load of office rooms. Indian Railways facilities have installed old and new AC units although most of the new AC units are 3 star rated. Production units consists of 80 nos. and workshops have 40 nos. AC units on average operating during summer period (March to August).

AC compressor unit is normally controlled by relay and timer to achieve the set temperature based on predefined algorithms for hottest region.

Conventional packed AC units have following problems:

- AC manufacturers cannot customize each unit to the different climates, therefore, designing a common control setting for the hottest conditions. This leads to huge wastage. When the set temperature is achieved, the compressor continues to run for an additional fixed period (6-8 minutes – known as the "Overcooling period") which is required only for few hours in a day in peak summer but is over-utilized because of the balance of time. Also, in hotter climates, by reducing the prefixed "off-time", the overcooling can be reduced substantially.
- Many AC's typically do not achieve the set temperatureespecially if it is set at 18oC or 19oC. As a result, the compressor runs continuously resulting in wastage of huge amount of electricitygiving rise to issues such as:
    a. Ice formation on the coil- reduced heat transfer and cooling.
    b. Motor and Compressor runat higher temperatures, increasingthe specific energy consumption by 30 -40%.
    c. Refrigerant liquefies leading to the risk of compressor seizing.
    d. Frequent maintenance issues

Project Description:

AC energy saver is a latest generation intelligent controller having external sensors which can be retrofitted in the existing packaged AC units to provide Artificial Intelligence with a set of powerful Algorithms to the AC to

save energy & life of the compressor. It has additional digital room temperature sensor similar toa precision AC to maintain the precise set temperature along with an additional programmable sensor to read, display "The Coil Temperature" and control "The Differential Temperature" after the set temperature is achieved which further enhances energy savings.

Energy saver lets you to program your Off-Time and Over-Cooling period based on your climate and day/night usage.The Coil sensor in energy saver will cut off the compressor at a Coil temperature programmed by the user and not onlysaves on energy consumption but also increases the life of the compressor and reducing breakdowns.

Cost Benefit Analysis:

The sample calculation of cost benefit analysis for Packed AC energy saver is shown below for one IR facility.

Description	Value	Unit
Average energy consumption of 1.5TR, 3 star Rated AC unit	1.566	kW
Total nos of AC units in the facility	80	
Total Load	125.3	kW
Average Energy Savings of AC units with Energy Saver	25.1	KW
Annual energy savings of AC units with energy saver	37584	kWh
Annual Saving	2.5	Rs. Lakh
Total Investment	3.6	Rs. Lakh
Simple Payback period	17	Months

Replication potential:

This proposal has a replication potential of all the 10 IR facilities and can be implemented in all the IR facilities.

Benefits:

By installing the intelligent energy saver, on a conservative basis, cost savings potential of Rs. 20 Lakhs can be achieved in all the Indian Railways facilities. The investment incurred by implementation of this proposal is Rs. 29 Lakhs, with a payback of 17 Months.

RENEWABLE ENERGY

15. Solarmill to Harness solar and Wind Energy

Renewable energy is deemed to be the best substitute for conventional fossil fuel. Implementation of renewable energy posts various challenges such as capital cost and consistency of power output, the latter can be solved by the installation of Solar Mill (Figure shown below). Solar mill can be installed on Rooftop to tap the energy from wind and solar.

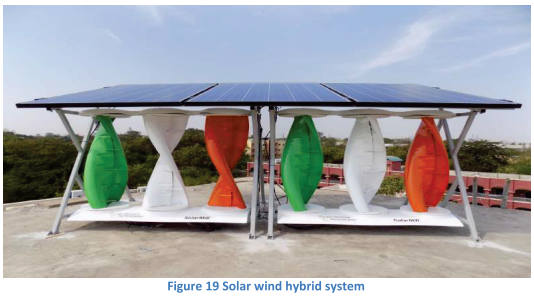


Figure 19 Solar wind hybrid system

The Solar Mill generates:

- Solar Energy during daytime
- Day & Night energy from the wind Energy
- Energy during overcast conditions
- More energy on hot sunny days due to cooling effect on solar panels by wind.

The solar mill consists of 3 vertical axis wind turbines coupled to three permanentmagnet generators. Automatic mechanical braking is provided once thewind speed goes beyond the cut-off speed. On-board smart electronicsinclude dynamic Maximum Power Point Tracking (MPPT). It uses wind andsolar resources on a 24/7 basis, allowing access to energy with minimal interruption of services. The design life of solar mill is 25 years.

Specifications:

The increase of renewable power per square foot of roof is obtained by combining two power sources.

For a roof top installation, combining solar and wind power is a complementary combination. For example, many locations are less windy in the middle of the day when the sun is at its peak, and the wind picks up after dusk.

Other advantages are solar module providing protection for the wind portions of the mechanism from direct rain and hail, and assisting with the direction of air into the turbines.

Since this compact installation is designed for rooftops and urban atmosphere, savonious type of wind turbine is chosen for its low running speed and relative insensitivity to turbulence.

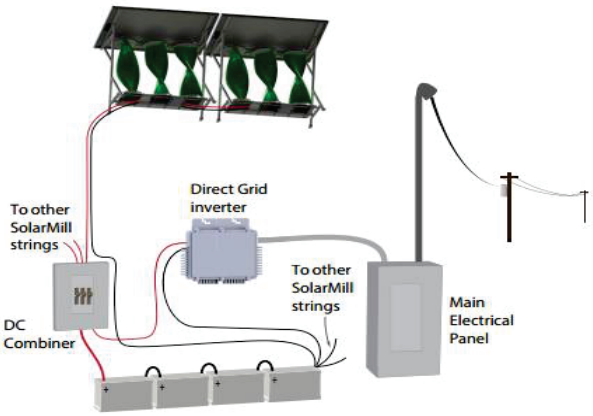


Figure 20 Hybrid mill connected to supply

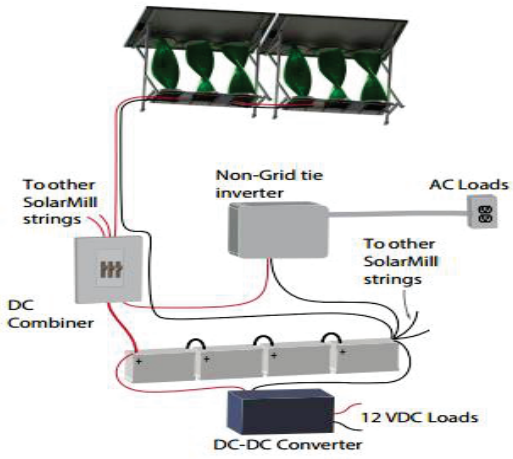


Figure 21 Hybrid mill connected to loads

Power generation begins at a cut-in speed of 2 mph and mechanical braking at high-speed winds beyond 18.5 m/s.

Independent MPPT for both wind and solar is calibrated. Maximum power point tracking (MPPT) is algorithm that included in charge controllers used for extracting maximum available power.

The power from both wind and solar generation is routed into a common 48V DC bus which has built-in charge control for a lead acid battery bank.

Also, in a grid tied system, the bank of batteries is connected to one or more Direct Grid micro-inverters which connect to the user's electrical panel. The inverters push power back to the grid efficiently when the batteries become fully charged.

In off-grid storage, the batteries can be used to supply power to electrical devices in off-grid settings. This electrical energy can power DC powered devices through a voltage converter, or can power AC devices through an inverter.

Cost Benefit Analysis:

The sample calculation of cost benefit analysis for a 50kWp solarmill is shown below for one IR facility is shown below:

Description	Value	Unit
Installed Capacity of Solar wind Mill	50	kWp
Average generation per day per kWp	8	kWh
Area Required	60	M2
Average Annual Energy Saving on conservative basis	132000	kWh
Annual cost savings	8.6	Rs. Lakhs
Investment	45	Rs. Lakhs
Simple Payback Period	63	Months

Replication Potential:

On grid 50kWp solarmill in 6 six production units and 25kWp solarmill in 4 workshops can be installed to cater the lighting and other general load of the shop floor.

Benefits:

By installing the solarmill On Grid system in all the 10 IR facilities, on a conservative basis, cost savings potential of Rs. 63 Lakhs can be achieved. The investment incurred by implementation of this proposal is Rs. 360 Lakhs, with a payback of 68 Months.

16. Bio gas plant for ConvertingOrganic Waste to Energy

Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source and in many cases exerts a very small carbon footprint.

Biogas is primarily methane (CH4) and carbon dioxide (CO2) and may have small amounts of hydrogen sulfide (H2S), moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel which can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat.

The input to the system could be tree waste from the plant and also food waste from the canteen present in the plant.

Process of Bio gas production from Waste:

Before the organic waste can be turned into biogas its size needs to be reduced, using a process called pretreatment. This can be done manually or using an industrial crusher, mixer or screw pump. Water is then added in order to achieve the particle concentration most suitable for the biological process. The resulting substrate, called slurry, is fed into the reactor manually, by machines or by pump-driven piping.

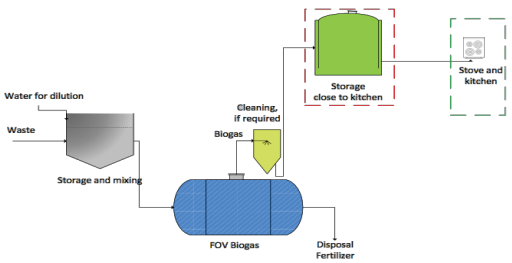


Figure 22 Block diagram of Bio gas plant

As soon as the slurry enters the reactor it starts taking part in the ongoing anaerobic digestion, i.e. the breakdown of organic material by bacteria (powered by nitrogen, phosphorous and other nutrients) and

enzymes in an oxygen-free environment. Biogas is the end product of this process.

As soon as the slurry enters the reactor it starts taking part in the ongoing anaerobic digestion, i.e. the breakdown of organic material by bacteria (powered by nitrogen, phosphorous and other nutrients) and enzymes in an oxygen-free environment. Biogas is the end product of this process.

The biogas is piped directly into houses, other buildings or a gas tank. It can also be converted into electricity by a generator or upgraded into biofuel and used for transportation.

The digestate contains a high amount of nitrogen, phosphates, and other nutrients. Some of the digestate is fed back into the reactor, thus saving water. The rest can be used as a high-quality organic fertilizer or can be sold.

Bio gas pants of different capacities can be setup based on the waste input capacity

Benefits:

Installation of bio gas plants yields the following benefits:

- Generation of useful fuel from food waste in the form of biogas
- Replacement of LPG with biogas for cooking
- Production of bio-manure as a by-product
- Reduction of GHG emissions

Figure 23 Practical bio gas plant

FURTHER OPPORTUNITITES TO ENHANCE ENERGY EFFICIENCY

17. Installation of Efficientdirect driven motors for AHUs

Project Background:

Air handling units (AHUs) are used to cater the HVAC load of the administrative building. These AHUS are operated with belt-pulley driven systems which accounts for belt slippage losses, resulting in 90% efficiency in transmission of the system. Normally induction motors are used for AHUs, operated at a loading of around 40-60%. As the motors are operated at loading below the rated value it is likely to give low efficiency and operate at a lower power factor. There is a potential of increasing the efficiency of the motor by replacing the existing ones with the new energy efficient motors.

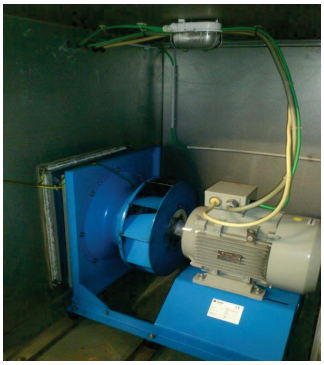
The latest technology for AHUs is to replace existing motors with direct driven energy efficient permeant magnet motors. This system comes with a speed control.

Project Description:

Replacing the old Belt -Pulley system with driven EC motors, 25 -30% savings can be achieved. Permanent magnet motors have better efficiency and power factor due to less stator and rotor losses.

Following are the advantages of using EC motors:

- Smooth rotation at low speeds: Brush motors are available which are specially designed for low speed smoothness with a large number of commutator segments. Brushed motors are the smoothest of the three discussed motor technologies.
- Low cost drive: A DC brush drive can be made very economically since only a single bridge circuit is required.
- No power used at standstill: with no static loads on the motor, any current is required to hold position.
- High peak torque available: In intermittent duty applications, particularly when positioning mainly-inertial loads, the motor can be overdriven beyond its continuous rating.
- Flat speed-torque curve: Gives optimum performance with easily generated linear acceleration ramps.
- Wide variety of types available: Brush motors are produced in many styles including very low inertia types for high dynamic applications.



Before (Induction motor)

After (Servo Motor)

Replication potential:

The proposed system has a replication potential of 30% and can be implemented in all the IR facilities where new AHUs are to be installed.

Benefits:

By installing the direct driven EC motors, on a conservative basis, 25% energy savings can be achieved when compared to the conventional belt pulley system.

18. Alternate fuel and combustion catalyst for Diesel

Project Background:

In various Indian Railways production units and workshops, diesel is consumed in furnaces for heat treatment of machined components. For furnaces using diesel as a fuel for combustion, the combustion efficiency of the fuel is a governing factor for the heat rate, which forms the measure to assess the performance of the furnace.

Poor combustion factor of the fuel leads to detrimental effects, namely:

- Poor Fuel Economy
- Incomplete & toxic exhaust emissions
- High maintenance cost
- High carbon scaling

For instance, one of the production units of Indian Railways utilizes approximately 11000 kL of diesel annually for heat treatment furnaces, excluding the quantity of fuel used for transport and engine test facility.

With combustion efficiency playing a key role in assessing the performance during operation, there exists potential to improve the combustion efficiency using diesel additives.

Project Description:

Latest advancements in fuels enables the combusting fuel to enhance the oxygenating capacity, providing more oxygen exposure to the molecules of the fuel. This conditions the fuel to instigate more clean combustion, reducing particulate emissions such as CO_2, SOX, NOX and CO, whilst maintaining the combustion quality.

Also, as a green initiative towards substituting diesel as a combustion fuel, bio-fuels are considered to be the next alternatives synthesized from plastic waste and converted to useful combustible fuel. These "Net Zero CO_2 Emission" fuels can be used as a direct substitute or blended with diesel at any ratio. Bio-Fuels are best applicable for combustion in kilns, boilers, hot air generators, etc. but not recommended for internal combustion machinery. The fuel can be a direct substitute without downgrading the calorific value of combustion, while keeping the particulate emissions minimum.

Replication Potential:

This proposal can be implemented in those units or workshops which utilizes external combustion techniques for heat treatment.

Benefits:

The benefits of using diesel additives are:

- Enhanced fuel efficiency
- Reduced toxic pollutants
- Less soot deposition
- Reduced maintenance cost

Blending/direct substitution of diesel with Bio-Fuels offers the following benefits:

- Replacement of diesel without infrastructural modifications
- Does not compromise on the Calorific value when compared with diesel
- Recycled from waste, therefore a substitute to incineration technology which emits toxic gases.

19. Battery Operated Electric Fork lifts

Project Background:

Indian Railway facilities have diesel operated fork lifts for material handling and each unit is having an average no of 10 forklifts of mostly 3Ton and 5Ton.Diesel operated fork lift have noise and fume emissions also the diesel forklifts are bigger and bulkier than the compact-sized electric-powered lift, and thus requires more room for overall storage inside a warehouse or plant. The operating cost of diesel one is much higher than the electric battery operated one.

Proposed technology:

Battery operated fork lift are more environmentally friendly than a diesel-powered forklift, an electric-powered lift truck is not only quieter than its alternative, it doesn't generate or release any harmful emissions into the air. These are particularly important aspects to consider if the lift truck is going to be primarily used indoors where workers would be directly and regularly exposed to the loud noise and fumes of a diesel-powered forklift. In addition, electric forklifts are more compact, easier to maneuver around small, tight spaces, and don't require their drivers to use a clutch. Further, an electric-powered forklift is less expensive to maintain than a diesel-powered forklift since it has less moving parts and a rechargeable battery (vs. regularly refilling a tank).The electric fork lifts are available in different lifting capacities starting from 1.5T to 5.5T.

Replication Potential:

This proposal can be implemented in those units or workshops which utilizes diesel operated forks for material handling.

Benefits:

The benefits of using diesel operated forklifts are as follows:

- Operating cost lower than Diesel operated forklifts
- No requirement of fuel storage
- Zero Emission
- Noiseless operation
- Reduction of wear and fatigue for the operator due to Automatic Braking
- Elimination of usage of engine oil and coolant
- Longer maintenance intervals

SUMMARY OF ENERGY EFFICIENCY MEASURES

The summary of the energy savings measures of various technologies, highlighting the energy and cost saving potential, and the investment incurred in implementation of the technologies is shown below:

S. No	List of technologies	Saving potential	Invest-ment	Payback	Energy Saving	TOE Reduction	CO_2 Reduction
		Rs. Lakhs	Rs. Lakhs	Months	Million Units	MTOE	Tonnes
1	Improving power factor close to unity	330	57	2	-	-	-
2	Isolating primary of Idle Running Distribution Transformers	46	-	-	0.71	61	636
3	Installation of Light Pipe to harness day light	9	20	27	0.14	12	125
4	Replacement of old welding sets with New Inverter based welding technology	130	360	34	2.01	173	1791
5	Regenerative drive for EOT carne Application	200	500	30	3.09	266	2755
6	Replacement of ceiling fans with Energy Efficient BLDC fans	80	210	32	1.22	105	1090
7	Installation of Energy management system to optimize plant energy consumption	200	120	7	0.25	22	229
8 A	Replacement of old reciprocating compressors with EE screw compressors with in-built VFD	160	520	39	2.47	213	2204
8 B	VFD for existing screw compressors						
9	Intelligent flow controller for compressed air network	100	125	15	1.57	136	1404
10	Transvector nozzle for compressed air cleaning application	10	8	10	0.15	13	138
11	Installation of Level sensor based auto drain valves	10	11	13	0.15	13	139
12	Opportunity to reduce compressed air leakage	50	0	0	0.77	67	689
13	Aluminum piping for compressed air network	37	132	43	0.57	49	510
14	Energy saver for packed AC units	20	29	17	0.30	27	276
15	Solarmill to Harness solar and Wind Energy	63	360	69	1.0	87	896

The summary of the energy savings measures does not include the energy saving in other technologies. By implementation of the above technologies in all the 10 facilities, 14.68 MU can be saved, equivalent to 1,263 MTOE reduction. Also, the carbon footprint can be reduced by 13,074 tCO2 per year.

ACTION PLAN AND CONCLUSION

Over the years, Indian Railways, has takensignificant measures towards promoting energy efficiency in both traction and non-traction areas. Though there are many initiatives taken by Indian Railways to reduce energy consumption through stringent guidelines/policies on General Power Supply Systems such as the use of LED lights, Star rated equipment, and websites dedicated to energy savings, challenges in various aspects such as technological, administrative, financial, etc., progress has been difficult and to adhere to these compliances.

Action Plan:

- The individual facilities have to assess the baseline performance and develop their own individual target for improving all the parameters.
- Set and achieve voluntary target of at least 2 to 5% reduction in specific energy consumption every year within defined timelines
- The best practices and the performance improvement projects compiled in this manual may be considered for implementation after suitably fine tuning to match the individual plant requirements.
- Formation of a cross functional energy team with an Energy Manager to implement study and implement various technologies.
- Identify specific person to facilitate implementation of the technology.
- The team must prioritize the projects based on short/medium/long term energy efficiency opportunity and implement in a phased manner
- If required, CII-Godrej GBC will help the individual units to improve the performance by providing energy audit services and identifying performance improvement projects specific to individual units to achieve the targets.
- The present level of performance and the improvements made by the individual units have to be monitored.

Conclusion:

The objective of the project will be fulfilled only if the performance of all the Indian Railways units improves and achieves world class standards.We are sure that the Indian Railways will make use of this manual to improve their performance, set benchmarks and become world class in Energy Efficiency.

ANNEXURE 1

METHODOLOGY ADOPTED FOR PILOT EE STUDIES

The following methodology was adopted to enhance energy efficiency in Indian railways:

1. Project Inception workshop
2. Awareness workshops and training programs for the officials on the technological aspect of energy efficiency and best practices adopted in related Indian industry and Identification of key energy saving opportunities
3. Missions for Indian Railway officials to best performing units in similar sectors in India such as automobile and engineering to help them absorb cutting edge technologies and practices.
4. Identify potential technology suppliers who have energy saving offerings for the IR and organize workshop/ meetings with them and other key stakeholders to ensure swift development of EE projects in the railway units
5. Conduct Energy Efficiency Award, on the sidelines of Annual CII Energy Efficiency Award for Railway units.Best performing units were felicitated within the IR system
6. Best Practices Manual for Energy efficiency in Indian Railways

1. Project Inception Workshop

Inception workshop meeting was held on 24th Oct 2016 at Rail Wheel Factory (RWF) Bangalore and all the Coordinators of the respective production units and workshop have participated and agenda of the Inception meeting is following:

- To Understand the various facilities participating in this engagement and their expectations
- Agree on action plan at various facilities
- Discuss timelines and deliverables at each engagement level
- Finalize the plan of visits for each of the 10 locations and other industries to be visited as part of the missions
- Tentative agenda for the technology workshops

The Outcome of the Inception workshop was following:

- Dates of plant visits, Missions and technology workshops will be finalized by Individual plant after formal communication letter from Central Indian Railways office
- Understanding basic details of IR facilities, operations, major energy consumers, typical energy bills and key energy efficiency initiatives taken in last two years

2. Training programs and Identified of Energy saving opportunities

CII delivered specific designed training programme to the Indian Railways professionals. The objective of these training programme is to disseminate knowledge on energy efficiency aspects on various equipment like Pumps, Fans, Compressors and compressed air systems, HVAC and air conditioning etc. and also share the best practices on the fronts of energy efficiency. The training programme also aims to provide in-depth knowledge about various regulations and financing mechanisms for Energy Efficiency Projects.

A Site Visit of 3 days was done at different facilities of Indian Railways to identify key energy saving opportunities and training program

The details of the activities carried out for three days were following:

1. Day-1 :
   a. Introduction with plantteam.
   b. Detailed discussion with the plant team on the process and equipment
   c. Walk through visit of the plant
2. Day 2:
   a. Training program and sharing of best practices by CII
   b. Doubt Clarification and Gemba Walk
   c. Discussion on the findings identified from plant visit and Gemba Walk
   d. Technology suppliers visit
3. Day 3 :
   a. Presentation by CII team on the findings
   b. Interactive session and Close

3. Mission to be best performing Engineering Unit of similar Nature

We have Facilitated focused missions of Indian railways professionals to 4 best performing plants like Tata Motors, Pune, Mahindra and Mahindra, Zaheerabad, Ashok Leyland Bhandara and Toyota Kirloskar, Bidadi. The objective of the mission was to showcase Indian Railways various energy efficiency initiatives taken by the similar units in India and understand the drivers, approach, involvement of all stakeholders, etc. that made energy efficiency improvements possible.

4. Technology supplier Workshop

Technology supplier workshops was conducted to make identification of technology options quicker and implementation of EE projects at Indian Railways faster. IR officials participated from different Indian Railway facilities and technology suppliers presented their technologies on following energy intensive areas:

- Compressors and compressed air system energy optimization
- Electrical system & lighting,
- Power Quality and Reactive power compensation
- Regenerative drive solution for EOT cranes
- Energy efficient BLDC ceiling fans
- Packed and split AC unit energy saver
- Inverter based wielding sets and other shop floor utilities and Renewable energy

5. Energy Efficiency Awards

We have conducted Energyefficiency award programs for Indian Railways alongside CII's energy awards in 2018, to showcase their initiatives to other industrial sectors as well. In 2017, 7 Indian Railway facilities participated in the energy efficiency award program and out which 4 facilities got shortlisted. Rail Wheel Factory, Bengaluru and Golden Rock Railway Workshop, Trichy received excellent energy efficient unit award and Integral Coach Factory, Chennai and Wagon Repair Workshop, Jhansi received energy efficient unit award.

6. Best Practice compilation

CII team visited the 10 Indian railways units for the identification of various energy saving opportunities with replicable potential across the production units/workshops and documented all the replicable energy saving potential.

ANNEXURE 2

CAPACITY OF IR MAJOR PORODUCTION UNITS:

Over the years, there has been improvement in design and capacity of locomotives, wagons and coaches through introduction of new technology. While the number of wagons has come down, total capacity has gone up. Similarly, seating capacity per coach has risen.

With an aim to provide greater fillip to Prime Minister's Make in India Campaign, Indian Railways has constantly endeavored to increase its production capacity through its production units as a result of which production output in last three fiscals of railway production units has consistently shown an increase. This has been possible due to capacity augmentation and technology up gradation.

The Railway major Production Units and their production output for the five consecutive years is given below:

Table 1: Output of Indian Railways Production units

S.No	Name of Production Unit.	Product	Production output				
			2012-13	2013-14	2014-15	2015-16	2016-17
1	Diesel Locomotive Works (DLW), Varanasi, UP.	Dsl. Loco	270	304	266	330	334
2	Chittaranjan Locomotive Works (CLW), Chittaranjan, West Bengal.	Elec. Loco	294	264	250	280	292
3	Integral Coach Factory (ICF), Perambur, Chennai, Tamil Nadu.	Coaches	1592	1604	1678	1997	2215
4	Rail Coach Factory (RCF), Kapurthala, Punjab.	Coaches	1635	1550	1480	1603	1489
5	Diesel Loco Modernization Works (DMW), Patiala, Punjab.	Loco manuf.& rebuilding	133	156	149	157	146
6	Rail Wheel Factory (RWF), Bangalore, Karnataka.	Wheels	191501	188188	175175	183001	130033
		Axles	100001	77406	72479	77419	74444

The capacity utilization of these Production Units during last consecutive five years is given below

Table 2: Capacity utilisation of Indian Railways

S.No.	Production Unit	Capacity Utilisation				
		2012-13	2013-14	2014-15	2015-16	2016-17
1	Diesel Locomotive Works (DLW), Varanasi, UP.	108%	122%	106%	132%	134%
2	Chittaranjan Locomotive Works (CLW), Chittaranjan, West Bengal.	135%	132%	125%	140%	146%
3	Integral Coach Factory (ICF), Perambur, Chennai, Tamil Nadu.	106%	107%	112%	117%	130%
4	Rail Coach Factory (RCF), Kapurthala, Punjab.	109%	103%	99%	107%	99%
5	Diesel Loco Modernization Works (DMW), Patiala, Punjab.	185%	217%	207%	218%	203%
6	RWF,Bengaluru- Wheels	101%	99%	92%	97%	69%
	RWF,Bengaluru-Axles	143%	111%	104%	111%	106%

The above is the data relating to Individual production units of Indian Railways.

The following is the overall trend of locomotives, wagons and passenger trains over the years.

Table 3: Statistical summary of Indian Railways

Year	Locomotives			Coaching vehicles			Wagons
	Steam	Diesel	Electric	Passenger	EMU.DMU/ DHMU	Other vehicles	
2012-2013	43	5345	4568	48037	9184	6792	244818
2013-2014	43	5,633	4,823	50,194	9,371	6,792	2,52,833
2014-2015	43	5,714	5,016	51,798	9,725	7,000	2,54,018
2015-2016	39	5,869	5,214	53,101	10,210	6,899	2,51,256

With increasing reliance on dieselization and electrification, IR has been reducing its fleet of steam locomotives.

The number of coaches and their capacity has grown over the years keeping in view the increasing passenger demand.

ANNEXURE 3

DETAILS OF TECHNOLOGY SUPPLIERS

VFD and Other Drives

ROCKWELL AUTOMATION INDIA PVT. LTD.
(Allen-Bradley India Ltd.)
C - 11, Industrial Area
Site - 4, Sahibabad
Ghaziabad - 201 010
Tel: +91 120 2895245, 2895252
Fax: +91 120 2895226

ASEA BROWN BOVERI (ABB) LTD.
Plot No. 5 & 6, II Phase
Peenya Industrial Area
P B No. 5806, Peenya
Bangalore - 560 058
Tel: +91 80 2294 9585
Fax: +91 80 2294 9389

YASKAWA INDIA PVT LTD
Mr. Sreekumar Naroli
Email ID: sreekumar_n@yaskawa.in
Ph: +91 9573770123

Inverter Based Welding Machines

ADOR FINOTECH
Mr. Krishna Kumar
Email ID: krishnakumar@adorfon.com
Ph: +91 93965 15582

Regenerative Drives – EOT Cranes

YASKAWA INDIA PVT LTD
Mr. Sreekumar Naroli
Email ID: sreekumar_n@yaskawa.in
Ph: +91 9573770123

Radiant Recuperative Heaters

THERMAX BABCOCK & WILCOX LIMITED
Energy Building, D1 Block, Plot No. 7/2
RD Aga Road, MIDC, Chinchwad
Pune 411019
Tel: 020 – 6612 6464, 6612 6411
Fax: 020 – 6612 6612

BLOOM COMBUSTION INDIA PVT. LTD.
Mr. Rahul
Email ID: rpathak@bloomeng.com
Ph: +91 9881001342

Energy efficient BLDC Ceiling fans

GORILLA FANS
Mr. Arindam
Email ID: arindam@atomberg.com
Ph: +91 9051503838

SUPERFANS
Mr. Sathish
Email ID:sathish@versadrives.com
Ph: +91 9488594382

Battery Operated Forklifts

TOYOTA MATERAILA HADNLING
Mr. Suresh Kasula
Email ID: kasula.s@tmhin.toyota-industries.com
Ph: +91 9100878731

GODREJ MATERIAL HANDLING
Mr. Ranganath
Email ID: rangnath@godrej.com
Ph: +91 9885286984

Electronically commuted Direct coupled motors for AHUs

EMB-PAPST
Mr. Gopinath
Email ID: gopinath.murugesan@in.ebmpapst.com
Ph: +91 9551070554

ADD TECH
Mr. Ravi Pandey
Email ID: ravi@aadtech.in
Ph: +91 9594627773

Compressors & Compressed Air Systems

ELGI INDUSTRIAL COMPLEX
Trichy Road, Singanallur
Coimbatore - 641 005
India. Tel: 0422 – 2589555
Fax: 0422 – 2573697

ATLAS COPCO COMPRESSOR
6-3-1191, 2nd Floor, BrijTarang
Greenlands, Begumpet
Hyderabad - 500016
Tel: +91 40 32949090
Fax: +91 40 23417923

GODREJ GROUP – EE SERVICES
Mr H N Daruwala
Godrej & Boyce Mfg. Co. Ltd.
Maharashtra,
India.
Ph: +91-22-6796 5656 / 67965959

HSD Blending Oil

MS SOLUTIONS
Mr. Nitin Bedi
Email ID: nitin@mssolutionsg1.in
Ph: +91 7730011144

Transvector Nozzles

GENERAL IMSUBS
Mr. Kushal Raj
Email ID: air@giplindia.com
Ph: +91 9327030174

Level sensor based Auto drain Valves

ORCHID INDUSTRIAL EQUIMENTS & ENERGY UTILITY SERVICES
Mr S Baskaran
Email ID: orchidie@eth.net
Ph: +91 94440 10371

Battery operated tools for riveting and grinding

BOSCH LIMITED

Mr M N Nabi Khan
Email ID: nabikhan.mn@in.bosch.com
Ph: +91 9963022188

Solar Wind Hybrid system

WINDSTREAM ENERGY TECHNOLOGIES
Mr. Bhaskar Sriram
Ph: +91 9959918782

Light Pipe

SKYSHADE
Mr. Srikanth
Email ID: srikanth@skyshade.in
Ph: +91 9394666885

kVAr Compensator

ATHENA CLEANTECH PVT LTD
Mr. Rishi Shroff
Email ID: rishi@cleantech.com.sg
Ph: +91 9820104126

Delta-Star With Intelligent Motor Protection device

ADVANCED MICROTECH
Mr. DeveshMukatiwala
Email ID: amtpower@gmail.com
Ph: +91 9427137301

Energy Management Systems

SEE-TECH SOLUTIONS PVT. LTD.
Manoj Telrandhe
Manager – Knowledge Based Businesses & IT
11/5, Lets Conserve, MIDC InfoTech Park
Near VRCE Telephone Exchange
South Ambazari Road, Nagpur-440 022
Mobile: +91-9975325831
Ph: 0712-2222177, Fax: 0712-2225293
Email: utisave@gmail.com
seemil_ngp@sancharnet.in

ATANDRA
Mr. Anish
Email ID: anish.amalraj@atandra.in
Ph: +91 9392609156

The Confederation of Indian Industry (Cll)

The Confederation of Indian Industry (Cll) works to create and sustain an environment conducive to the development of India, partnering industry, Government, and civil society, through advisory and consultative processes.

Cll is a non-government, not-for-profit, industry-led and industry-managed organization, playing a proactive role in India's development process. Founded in 1895, India's premier business association has over 8000 members, from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 200,000 enterprises from around 240 national and regional sectoral industry bodies.

CII-Sohrabji Godrej Green Business Centre(CII-Godrej GBC) was established in the year 2004,as CII's Development Institute of Green Practices & Business, aimed at offering world class advisory services on conservation of natural resources. The Green Business Centre in Hyderabad is housed one of the largest buildings in the world and through Indian Green Building Council(IGBC) is spreading the Green Building movement in the country. The Green Business centre was inaugurated by His Excellency Dr. A.P.J Abdul Kamal, the then President of India on 14July 2004.

The Services of Green Business Centre Include – Energy management, Green Buildings, Green companies rating, Renewable Energy, GHG Inventorization, Green Product Certification, Waste Management and Cleaner Production Process. CII- Godrej GBC works closely with the stakeholders in facilitating India emerge as one of the leaders in Green Business by the year 2022.

Shakti Sustainable Energy Foundation

Shakti Sustainable Energy Foundation works to strengthen the energy security of the country by aiding the design and implementation of policies that encourage energy efficiency as well as renewable energy. Based on both energy savings and carbon mitigation potential, it focuses on four broad sectors: Power, Transport, Energy Efficiency and Climate Policy. Shakti acts as a systems integrator, bringing together key stakeholders including government, civil society and business in strategic ways, to enable clean energy policies in these sectors. For more information, please visit http://www.shaktifoundation.in

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