Excellence in Metro Operations and Management:

Best Practices World Over

Energy Management System

Sharat Sharma
Former Director Operations
Delhi Metro Rail Corporation

INTRODUCTION

- Transportation in general and Metro Operations is energy Intensive.
- Transport sector accounts for nearly 18% of total energy consumed in India.
- Electricity is used as Energy in metro systems
- Larger is the metro more energy intensive is the metro operations.

INTRODUCTION

- Why Energy Management System is important for metro?
- Mostly electricity is generated from the fossil fuel (Thermal Power plants), which generates more carbon emission leading to climate change.
- Energy tariff is such that it results in high working expanses,
- Therefore, the energy consumption is to be reduced
- Monitoring of energy consumption and its benchmarking is important.

INTRODUCTION

- As per reports of Ministry of Environment, Forest and Climate Change (MoEFCC) study, after Energy sector, transport sector is the second largest contributor to CO_2 of which road transport contributes 87% of total CO_2 equivalent.
- Road and rail transport generates the bulk of transport emission.
- The transport sector or at the Global level continues to get grow unabated, which gives a business as usual (BAU) emission scenario of 12-13 $GtCO_2e$ per year by 2050.
- In Dec 2009, India announced that it would aim to reduce the GHG emission intensity of its GDP by 20 - 25% (NDC 30 - 35%) by 2020 (NDC -2030) from its level of 2005).

INTRODUCTION

- Energy is consumed in traction and other Auxiliary services of Metro
- Traction Energy is the Energy used to run the train services and
- Non-Traction Energy- energy used for running stations, depot and building auxiliary services.
- Typically, around one-third of the working expenses of a metro rail is on electric power tariff. If there is no subsidy.
- Therefore, proper planning during the design and operation stage is imperative.

ENERGY CONSUMPTION AT A GLANCE

- Annual ridership and energy consumption

Network and Energy Consumption)

Line	Length (km)	Number of stations				Annual ridership (In millions)	Annual energy consumption (in MU)
		Elevated	At grade	Underground	Total		
1	25.09	20	1	–	21	131.92	77.94
2	49.43	17	–	20	37	361.56	292.4
3	58.68	46	2	4	52	376.00	241.32
4							
5	18.46	15	1	–	16	37.45	31.25
6	38.16	21	–	7	28	100.09	109.37
APL	22.70	1	–	5	6	14.40	37.51
Total	212.52	120	4	36	160	1021.41	789.79

Energy consumption

- 2.16 million units (MU) per day.
- 3.72 MU/ per route km and
- 0.77 million units per passenger.

Energy Consumption for the DMRC Lines

S No	Description			Units (In MU) in a year	Percentage share
1	Traction			511.54	68.0%
2	Non-Traction	a) Underground stations	113.00 MU	222.55	29.6%
		b) Elevated stations	57.26 MU		
		c) Property development	35.87 MU		
		d) Depots & HQ building	16.42 MU		
3	Losses and error			18.19	02.4%
4	Total			752.28	100%

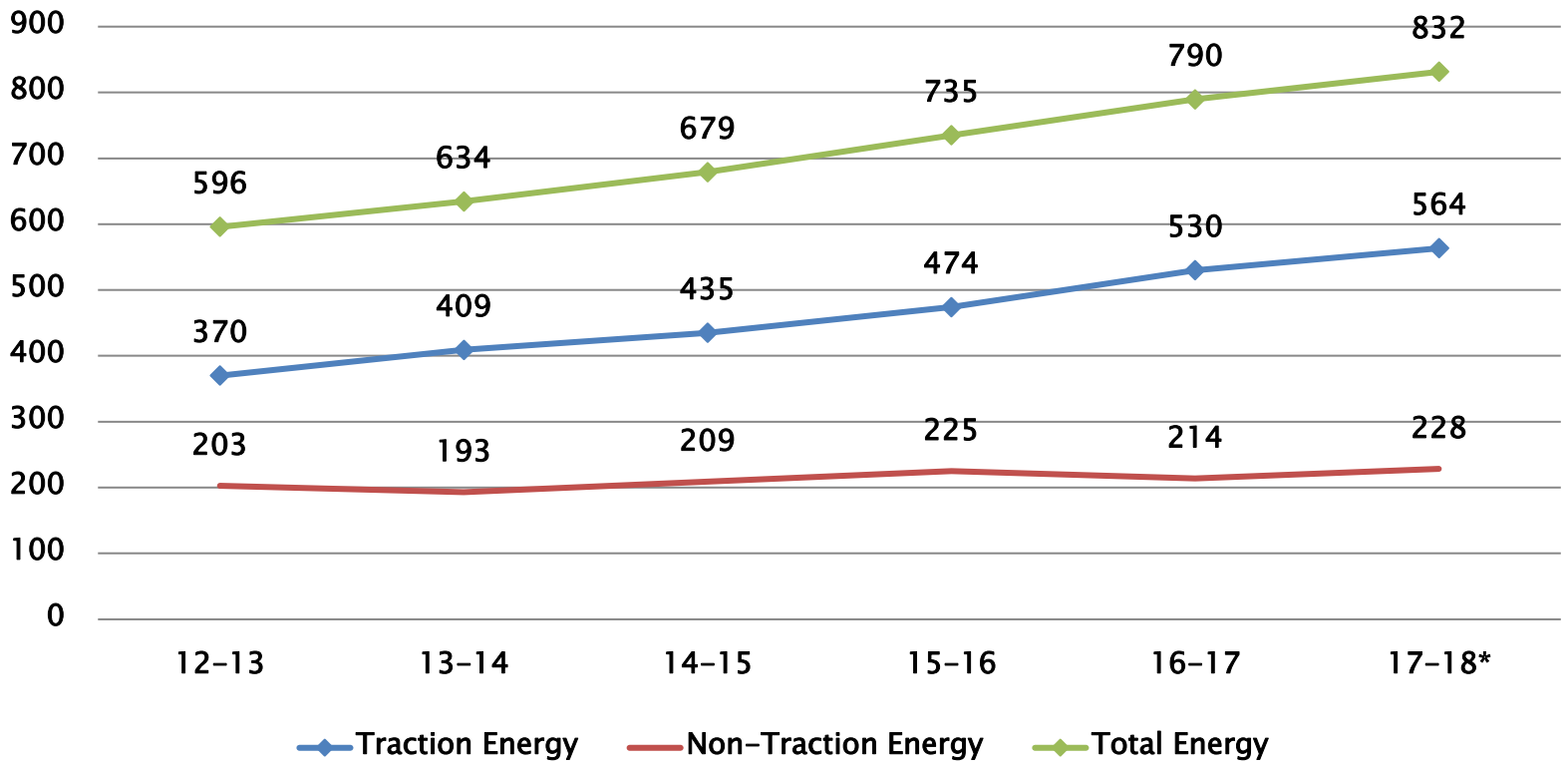
- *Traction Energy – Around 68 %*
- *Non- traction – 32% in other auxiliary services for various passenger facilities at stations such as air conditioning, lighting, fire & hydraulics, lifts, escalators & loses.*

Energy Consumption of Airport Express Line

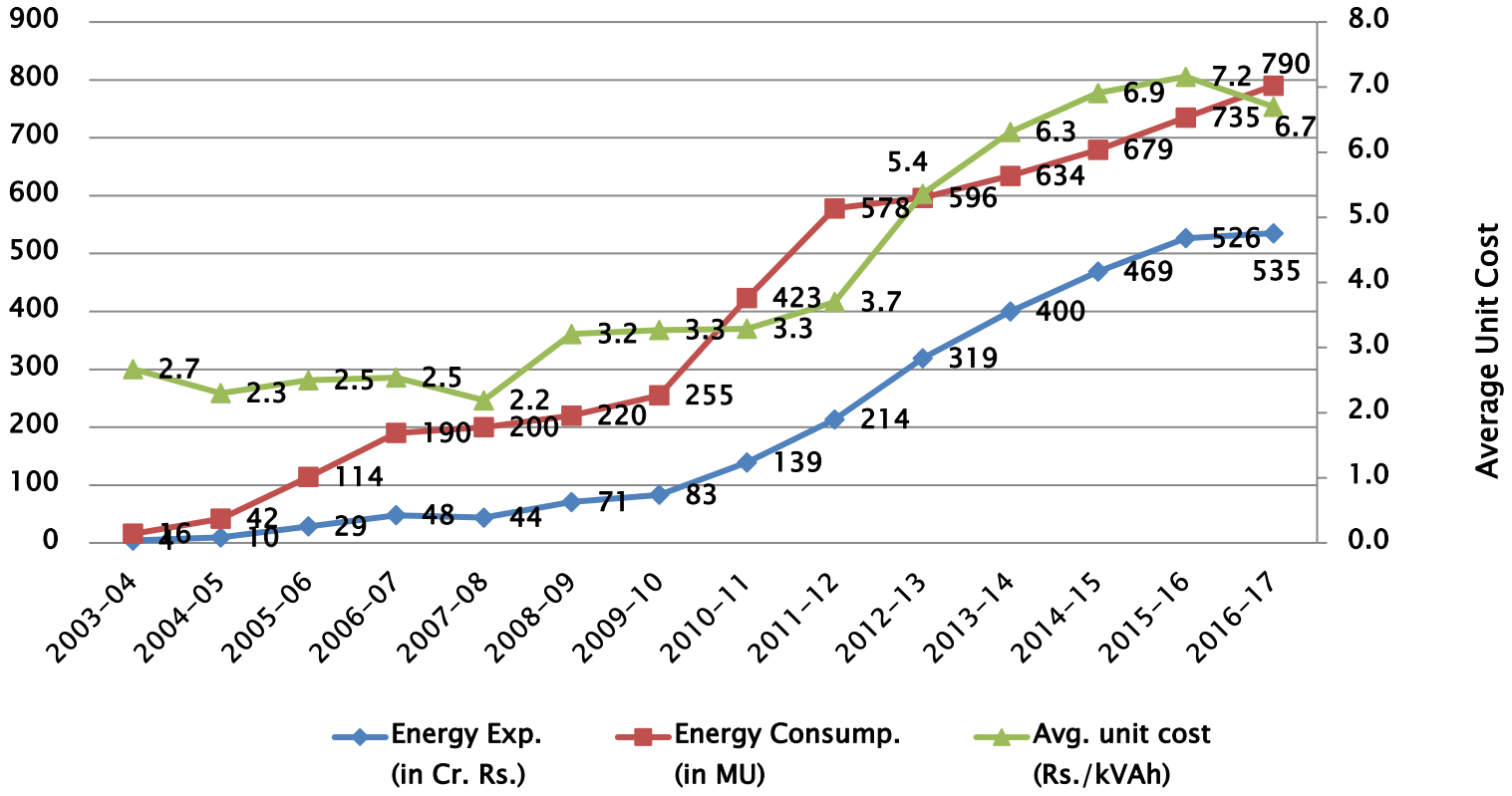
S. No	Description			Units (In MU) in a year	percent share
1	Traction			18.59	49.56%
2	Non-Traction	a) Underground stations	11.70 MU	18.24	48.63%
		b) Elevated stations	01.78 MU		
		c) Property development	03.12 MU		
		d) Depot	01.64 MU		
3	Losses and error			0.68	01.81%
4	Total			37.51	100.00%

- *In the case of the Airport line, the proportion of traction energy consumption is less (50%) as compared to the other DMRC lines (68%),*
- *Because of the low frequency (10 minutes) of trains and relatively larger property business formats at Airport line as compared to the other metro lines.*

Traction Energy Vs Non –Traction Energy Consumption pattern



ENERGY CONSUMPTION AND ENERGY EXPENDITURE PATTERN

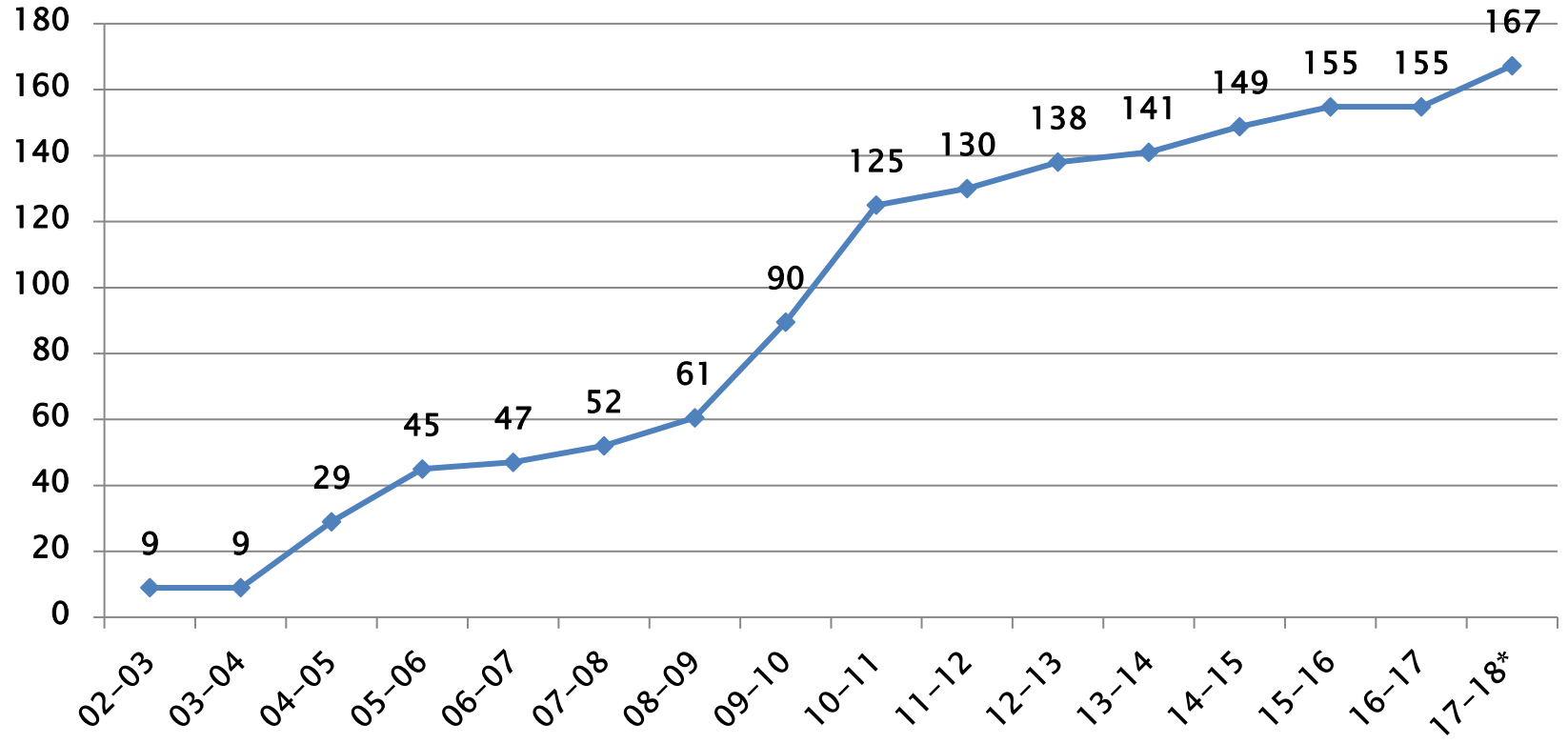


To optimize the working expenses on energy, monitoring, and controlling Energy efficiency and Energy consumption is imperative.

ENERGY CONSUMPTION AND ENERGY EXPENDITURE PATTERN

- The power is received at an extra-high voltage level of 220 kV,132 kV or 66 kV from various DISCOMS.
- The voltage is stepped down to 25 kV single phase AC for traction and 33 kV three phase for all auxiliary services at the metro operator's owned receiving substations.
- The sanctioned contract demand was 167 MVA.
- Energy consumption in 13 years increased from 3 MU to 790 MU i.e., 262 times.
- The price for Energy has risen from Rs 2.70 to Rs. 6.70 per kVAH- 2.5 times.
- As a result, the expenditure on Energy has risen from Rs 6 cr. to Rs 535 cr, i.e., by 90 times.

Contract demand pattern for the same period

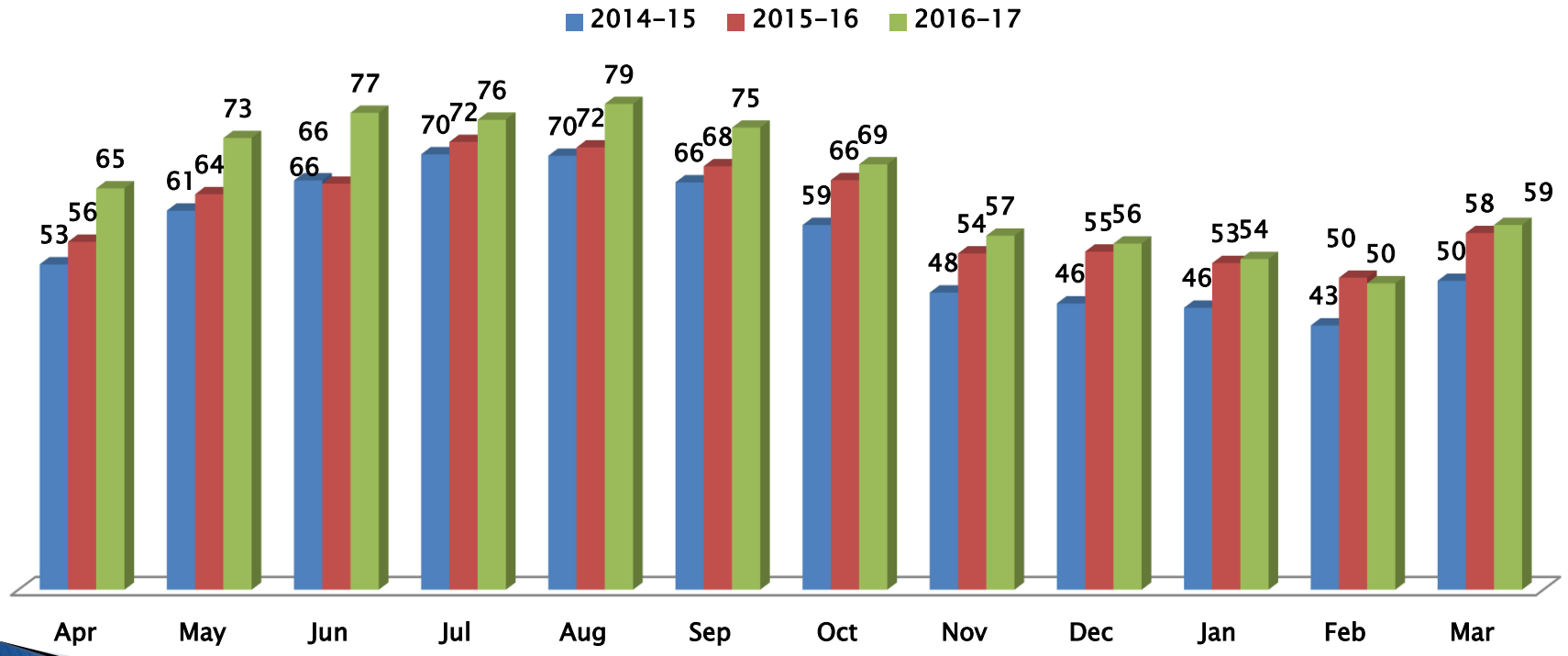


Energy conservation measures

- Traction energy consumption depends upon
  - frequency of trains
  - load of the train,
  - terrain of the section,
  - type of section, whether, underground, elevated, or at grade, and
- Initially, the auxiliary energy consumption is proportionately higher, as the train frequency and ridership increase with time the traction energy consumption proportion gets higher.
- In a matured system the proportionate traction energy consumption improves.
- The right driving techniques and benchmarking of energy consumption assumes importance and are to be adopted right from the beginning itself.

NON-TRACTION ENERGY CONSUMPTION PATTERN

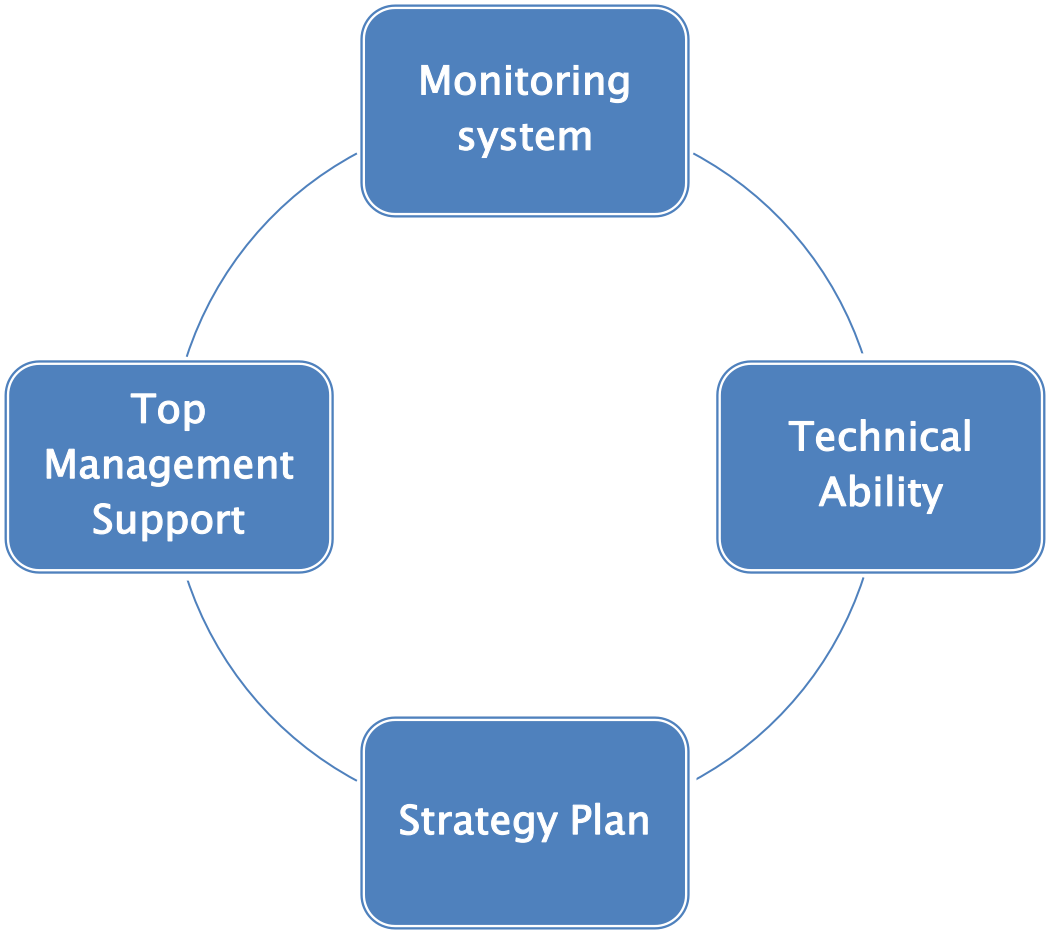
Owing to higher air conditioning loads during the rainy season, energy consumption is the highest in July and August while in February it is the lowest.



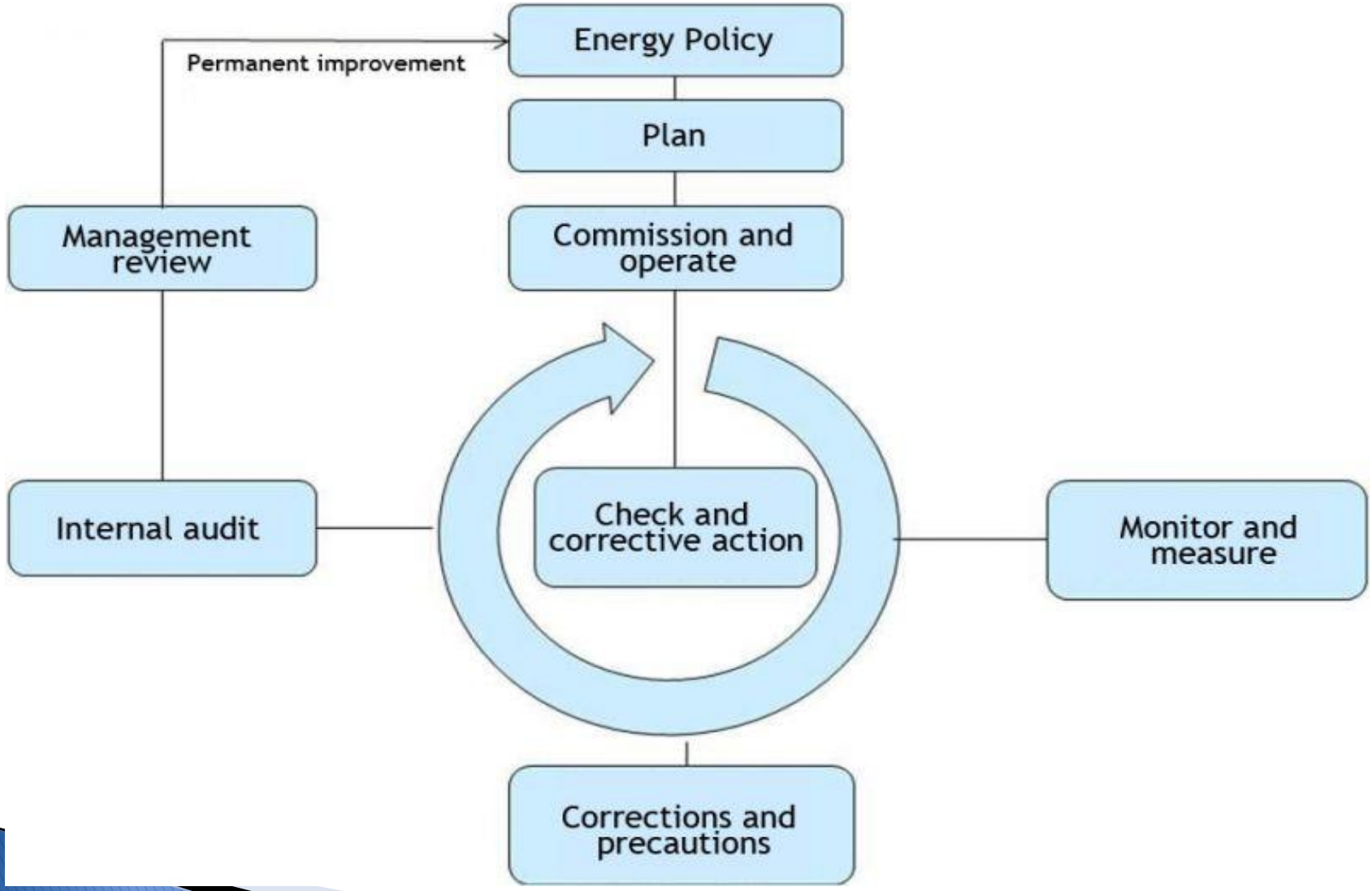
ENERGY MANAGEMENT SYSTEM

- Energy Management (EM) is to establish the systems and processes necessary to improve energy performance.
- Energy management system (EMS) is to reduce
  - greenhouses gas emissions with other related environmental impacts and
  - energy prices through systematic management of power and energy.
- EMS is essential for both the financial and environmental sustainability of the organization.
- EMS is important for operations and maintenance too.

Four Pillars Of Energy Management System



Typical Energy Management model



Significance of Energy Management System

- Combating Climate Change and Reduce Dependency On Non-Renewable Resources of Energy
- Sustainability
- Corporate Social Responsibility

Significance of Energy Management System

- DMRC adopted
  - ISO 50001and
  - Green Residential Societies Rating System

Certification Level	Recognition
Certified	Best practices
Silver	Outstanding performance
Gold	National excellence
Platinum	Global leadership

  - Benefits:
    - 20 to 30 % reduction in energy cost
    - 30 to 50 % reduction in water requirement
    - Improved health and wellbeing of the occupants.

Energy Conservation Policy- ECP

- DMRC unveiled ECP in 2008 revised in 2012 and again in 2015 identifying various fields, and measures suggested to ensure optimization of energy consumption by a systematic review.
- An action plan was formulated and implemented.
- Revised policy has provided a new direction in the field of energy management through systematic planning and its implementation to fulfill objective of:
  - Optimizing energy performance
  - Reduced operating cost
  - Minimise energy cost
  - Reduce environmental impact associated with energy use.

Policies

DELHI METRO RAIL CORPORATION LIMITED
दिल्ली मेट्रो रेल कॉर्पोरेशन लिमिटेड

ऊर्जा प्रबंधन नीति 2015

दिल्ली मेट्रो रेल कॉर्पोरेशन लिमिटेड दिल्ली राज्य एवं राष्ट्रीय राजधानी क्षेत्र में स्वच्छ और आरामदायक सार्वजनिक रेल परिवहन प्रणाली उपलब्ध कराने और परिवहन उद्योग में सभी परिवहन साधनों की अपेक्षा न्यूनतम ऊर्जा खपत करने वाली मेट्रो बनने के लिए वचनबद्ध है।

1. ऊर्जा की खपत, उसके उपयोग और ऊर्जा की बचत से संबंधित सभी संगत विधानों और उससे संबंधित जरूरतों का अनुपालन सुनिश्चित करना।
2. नवीकरणीय ऊर्जा स्रोतों के उपयोग जहां तक यह आर्थिक दृष्टिकोण से व्यावहारिक हो, को प्रोत्साहित करना ।
3. ऊर्जा की खपत के मापदंड़ तय करना।
4. ऊर्जा की खपत का सदुपयोग करना और ग्रीन हाउस गैसों को कम करना।
5. समय समय पर समीक्षा कर ऊर्जा की खपत पर निगरानी रखना, इसे नियंत्रित करना और एक कारगर ऊर्जा प्रबंधन प्रणाली द्वारा ऊर्जा की खपत में सुधार लाना।
6. न्यूनतम लागत पर बिजली प्राप्त करना।
7. कर्मचारियों में ऊर्जा संरक्षण के बारे में जागरूकता पैदा करना।

"दिल्ली मेट्रो रेल कॉर्पोरेशन लिमिटेड ऊर्जा संरक्षण के लिए वचनबद्ध है।"

ऊर्जा संरक्षण दिवस
दिनांक: 14.12.2015
स्थान: नई दिल्ली

मंगू सिंह
प्रबंध निदेशक

Energy Management Policy 2015

DELHI METRO RAIL CORPORATION Ltd. is committed to provide clean and comfortable public transport network in the state of Delhi & NCR and to be the lowest energy consumer in the Transportation sector on likewise basis.

1. Assuring compliance of all relevant legislation and other requirements related to energy consumption, its use and Energy efficiency.
2. Encourage use of renewable energy sources to the extent it is economically viable.
3. Benchmark energy consumption.
4. Optimize energy consumption and reduce green house gases.
5. Control & Monitor Energy consumption by periodic review and improve energy performance through an effective Energy Management System.
6. To obtain Power at minimum cost.
7. Create awareness about Energy Conservation amongst the employees.

"Delhi Metro Rail Corporation Ltd. is committed to energy conservation."

Energy Conservation Day
Date: 14.12.2015
Place: New Delhi

Mangu Singh
Managing Director

DELHI METRO RAIL CORPORATION LIMITED
दिल्ली मेट्रो रेल कॉर्पोरेशन लिमिटेड

सौर्य नीति

दिल्ली मेट्रो रेल कॉर्पोरेशन (डीएमआरसी), राष्ट्रीय सौर्य मिशन के उद्देश्यों को ध्यान में रखते हुए, पूरी तरह से लगातार स्थापित करने और ग्रीन हाउस गैस के उत्सर्जन और जलवायु परिवर्तन से संबंधित प्रभावों को कम करने के लिए सौर्य ऊर्जा का निरंतर उपयोग को बढ़ावा देने के लिए प्रतिबद्ध है।

तदानुसार, पर्यावरण अनुकूल और स्वच्छ ऊर्जा को बढ़ावा देने की खोज में, संगठन के रूप में जहाँ तक संभव हो, अपनी सभी गतिविधियों में सौर्य ऊर्जा के उपयोग के लिए प्रोत्साहित रहेंगे।

डीएमआरसी का प्रयास रहेगा कि:

- अपनी ऊर्जा जरूरतों को पूरा करने और जीवाश्म ईंधन पर निर्भरता कम करने के लिए एक दीर्घकालिक स्थायी समाधान हो।
- अपने संगठन में कुल बिजली की खपत में नवीकरणीय ऊर्जा की हिस्सेदारी बढ़ाने के उद्देश्य से अगले तीन वर्षों में गैर कर्षण प्रयोजनों के लिए 20 मेगावाट सौर्य ऊर्जा का उत्पादन हो।
- एक उपयुक्त निवेश माहौल बने जिससे क्लीन डेवलपमेंट मैकेनिज्म (सीडीएम) और ऊर्जा प्रमाणपत्र (आरईसी) का लाभ उठाया जा सके।

यह सौर्य नीति, संगठन के ऊर्जा प्रबंधन नीति के साथ संयोजन के रूप में पढ़ी जाएगी। डीएमआरसी सौर्य ऊर्जा से संबंधित सभी स्थानीय और राष्ट्रीय कानून का पालन करेगी।

मंगू सिंह
प्रबंध निदेशक
तिथि : 16 जुलाई 2014
स्थान : नई दिल्ली

SOLAR POLICY

Delhi Metro Rail Corporation (DMRC), in keeping with the objectives of National Solar Mission, is fully committed to proactively establishing and promoting sustained use of Solar Energy to reduce green house gas emissions and related impacts of climate change.

Accordingly, in pursuit of promoting green and clean power, the organization will encourage the use of Solar Energy in all its activities, as far as possible.

DMRC shall strive to:

- Seek a long term sustainable solution to meet its energy needs and reduce dependency on fossil fuels.
- Increase the share of renewable energy in its overall power consumption, in-house, by generating 20 MW of solar power for non-traction purposes, in next three years.
- Put in place an appropriate investment climate, that could leverage the Clean Development Mechanism (CDM) and Renewable Energy Certificate (REC).

This policy shall be read in conjunction with the organization's Energy Management Policy. DMRC shall comply with all local and national legislation related to solar energy.

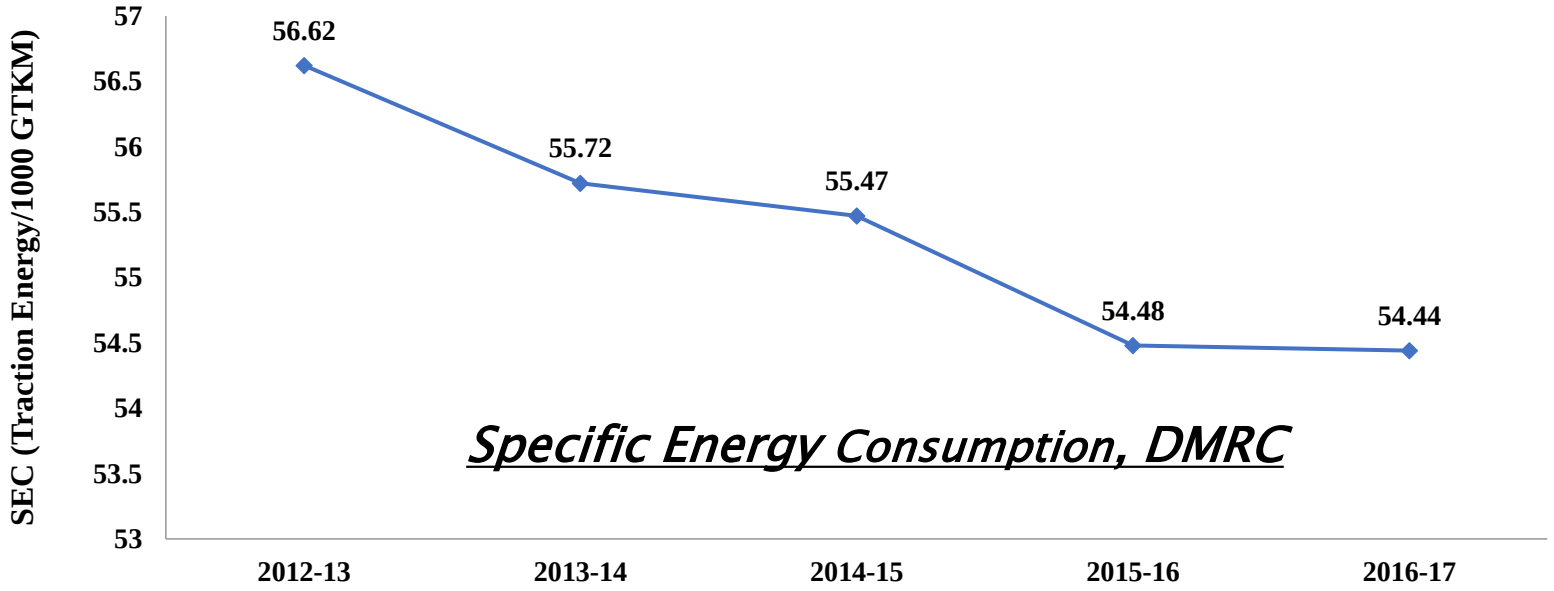
Mangu Singh
Managing Director
16th July 2014
New Delhi

Solar Policy- Use of Renewable Energy

- Renewable energy sources were explored and divested as per **Solar Energy Policy- 2014.**
- DMRC and the Solar Energy Corporation of India (SECI) signed a (MoU) in September 2013, to commission solar power in the Delhi Metro premises.
- Both collaborated for the development of solar projects at identified sites to produce solar energy.
- Renewable Energy Service Company (RESCO) model has been adopted
- Already installed approximately 50 MWp capacity of rooftop solar power.
- This would then ensure that1/3rd of the current power requirement is met from the renewable energy.

Specific Energy Consumption of Traction System

- SEC=Traction Energy consumption kwh/thousand gross ton-km.



- Reduction in SEC shown in the graph below is attributable to
  - an increase in ridership.
  - Measures taken to rationalization of trains as per the traffic demand, improved driving techniques, switching-off of redundant traction transformers, etc.

Acts and codes are followed during the project and O&M stages.

- Indian Electricity Act – 2003
- The Energy Conservation Act – 2001
- Energy Conservation Building Code 2007 amended up to date.
- National Building Code – 2005
- Central Electricity Authority Amendment Regulations (CERA) 2015
- I.S. Codes.
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)manuals and journals.

Measures taken to minimize Energy Consumption

a) Construction of most of the stations on a hump.
b) Design of coaches:
   - Reduction in the tare weight of coach by the use of stainless steel
   - Increased passenger capacity per coach
   - Variable voltage variable frequency drives
   - Choice of acceptable environment conditions inside the coaches and stations areas using Relative Warmth Index (RWI).
   - Use of regenerative braking leads to energy saving of about 30 to 40 percent of traction energy.

Measures taken to minimize Energy Consumption

- During the regenerative braking traction motors are run as generators.
- The achieved amount of regenerative energy depends on the train speed and the load of each car.
- Energy generated from regenerative braking is used in the train auxiliary system and the remaining portion (if possible) is fed back to the catenary system.
- Energy regenerated in three types of rolling stock (RS1, RS2 and RS3) in one financial year is tabulated

Stock	Total car km earned	Total energy consumption (kWh)	Total energy regeneration (kWh)	Regeneration per car km (kWh/km)	% Regeneration with respect to total consumption
RS-1	6,15,97,640	24,84,71,350	9,62,30,548	1.5	39%
RS-2	9,81,01,915	36,44,92,297	14,11,43,279	1.4	39%
RS-3	4,04,93,912	13,75,49,091	5,43,49,988	1.3	40%

Measures taken to minimize Energy Consumption

C) Traction

- Selection of 25 kV ac traction, which resulted in a reduction in the equipment sizing, lower losses of energy in the equipment, and in turn a more efficient system.

D) Underground Stations

- Selection of a closed system, where the conditioned air gets re-circulated
- Adopting of 1% design criterion or air-conditioning of underground stations.
- Selection of energy efficient Ventilation and Air Conditioning (VAC)equipment.
- Skylights have been provided in underground stations to maximize the use of daylight.
- In Phase-III of DMRC, all lights provided are LED.
- In Phase -II, Energy efficient 18,000 T-8, 80-NG tube lights with 93 Lumen/watt efficiency and 55,000, T-8 tube lights with 67 lumen/watt efficiency have been provided on elevated stations.

Measures taken to minimize Energy Consumption

- Gradually these will be replaced with LEDs.
- Lighting in underground stations has four circuits, each having 25% of the lights, making it easy to put off every fourth light.
- Lifts and escalators & Airconditioning, Ventilation equipment provided with variable voltage variable frequency (VVVF) control drives.
- Escalators are provided with the idling speed of 0.2 m/sec against the normal operating speed of 0.5 m/sec or 0.65 m/Sec.
- Phase-III lifts and escalators are provided with the regenerative braking system.
- The temperature inside the trains is set in accordance with ambient temperature.
- Monitoring of driving technique.
- Closing of car doors during testing to avoid air-conditioning leakages.

Measures taken to minimize Energy Consumption

- Limit switch is provided with door opening to control lights of the technical rooms.
- Energy-saving through optimizing timing for running of Air Handling Units (AHUs) as per the passenger flow in the station.
- Energy-efficient rolling stock improved driving technique and the use of ATO.
- Automation of pumps.
- Keeping the stand-by transformers as a cold standby instead of hot stand-by avoiding no-load losses
- Resetting of the air-conditioned room temperature at 28°C instead of 25°C excluding equipment rooms.

CERTIFICATIONS OBTAINED BY DMRC

- Delhi Metro has been certified by the UN as the first metro rail-based systems in the world to get carbon credits two projects - modal shift and regenerative braking.
- DMRC has been awarded Integrated Management System (IMS) certification in accordance with ISO 9001:2008, ISO 14001:2004 & OHSAS 18001:2007 standards.
- In line with its commitment to improve, DMRC got itself certified for ISO 9001 (Quality Management Systems), ISO 14001 (Environmental Management Systems), and ISO 18001 (Occupational Hazards).

CONCLUSION

- Metro systems, being energy intensive operations, substantial part of the working expenses is that of energy cost.
- Energy management must address both the fronts i.e., optimize energy consumption and reduce the cost of energy.
- Provide the most energy-efficient equipment, maintain them as per the design condition, monitor its usage and avoid wastages.
- Avail cheaper renewable energy as much as possible is a prerequisite.
- A focused approach and meticulous implementation only will yield the best results.

"Every act of energy conservation... is more than just common sense: I tell you it is an act of patriotism."

Jimmy Carter

Thank You

for Listening to me patiently