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CARRIAGE REPAIR WORKSHOPS ON INDIAN RAILWAYS: STUDY ON ENERGY CONSERVATION POTENTIAL

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ABSTRACT

Indian Railways has 45 workshops for maintenance of its fleet of rolling stock and out of them two workshops catering to broad guage coach maintenance located in southern part of India have been studied for a period of five calendar years from 2007 till 2011 to analyse their output and the corresponding energy inputs. The various activities of the workshops viz. maintenance of coaches and other major works have been studied with respect to energy usage to arrive at a common unit of output for comparison. All the forms of energy input to these two workshops viz. Electricity supply from distribution companies, high speed diesel and LPG have been accounted for. The study finds that the energy requirement for undertaking the periodical overhauling activity per coach in both the workshops is showing a downward trend from a peak of 1110 kWh per coach during 2007 to less than 600 kWh as in 2011 which is gradual and consistent and correspondingly the total energy consumption and the power bill of both the workshops over the period have shown a declining trend. The study finds that both the workshops have introduced various measures to conserve energy which has contributed to the reduced energy intensity. The larger workshop due to effective electricity management consumes 553 kWh per equated non ac coach periodical overhaul when compared to 700 kWh consumed by the smaller one. This provides for an energy saving potential of 15% per annum per workshop if better technologies are implemented and are managed properly.

Keywords: Carriage Repair Workshops, Periodical Overhaul of Coaches, Energy Efficiency, Energy Conservation, Energy Audit

1. INTRODUCTION

Energy is an important resource for economic growth and human comfort and its need over the years has been increasing considerably calling for considerable attention keeping in mind the related environmental implications. The need for energy is going to increase further due to increase in population and the comfort levels of human beings, be it in the form of transportation, accommodation, life style and the overall growth in infrastructure.

India during 2011- 12 imported 25.5 million tons of crude oil which constitutes 78% of nation's crude oil requirements at a cost of Rs 4, 88,550 Crores [1] . India is perennially an energy dependent nation and has to focus on both supply side as well as demand side management to manage its energy requirements in years to come. Indian annual electricity deficit is 10.3% or 96367 Million Units and peak deficit is 12.9% or 17517 MW which is evident from poor quality of power supplied in rural areas and frequent power cuts in urban areas. India's network of roads, railways, ports and air services is one of the largest in the world, serving more than 1 billion people. The total transport handled in the country is 800 tonne km of freight and 2300 billion km of passenger traffic. The total energy demand has grown at a rate of 10% annually in the past decade and by the year 2030 India will be the third largest energy consumer in the world. The present energy consumption

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by fuel shows that the transport sector consumes 98.5% energy from petroleum and balance 1.5% from other sources.

Indian Railways (IR) is the nation's transport lifeline and India's largest transporter connecting, integrating the country and moving men and materials from one place to another. IR moves 2.2 million ton of freight and 22 million passengers on a day to day basis 24 x 7 for all 365 days [2]. Railways are economical and environmentally friendly mode of transport as it consumes $1/5^{th}$ of the energy vis-à-vis road transport but faces the challenge in poor delivery and speedy delivery in short circles, especially for lower volume of consignment. If GDP growth is 10 % per annum and if railways have to carry 20% of the freight by 2020 there would be a six fold increase in total railway freight and 4 fold increase in passenger traffic which would put tremendous pressure on the energy requirement [3].

IR is plying 19000 trains every day which includes 12000 passenger trains carrying 220 lakh passengers per day by utilizing its fleet of 9000 locomotives and 51,030 coaches over a route of 63,974 kms. IR consumed 15,509 Million KWH of electricity and 2500 million liters of diesel during 2009-10[4], for its operations involving traction and non-traction applications. Energy costs amounts to 24 % of total operating expenses of IR and with Rs 18,000 Crores spent of fuel expenses IR is India's largest energy consumer, be it in the form of electricity or diesel. Energy is consumed mainly for traction purposes i.e., to haul passenger and freight trains and for its establishments such as stations, yards, workshops, sheds, carriage and wagon depots. Workshops are the places where full-fledged maintenance is carried out on the rolling stock viz. locomotives, coaches and wagons and IR has 45 such workshops placed over 17 zones. Next to traction workshops consume the highest amount of energy in the form of electricity and hence this study is being undertaken to study their energy requirements and find potential areas for conservation.

To achieve this objective effectively IR has over the years created large infrastructure and a good management system to ensure that it is fully utilizing all the resources at its disposal viz., human resources, workshops, sheds, Carriage & Wagon depots, etc. on a 24 x 7 x 365 basis and has focused on efficiency, operation and safety. The fleet of locomotives, coaches and freight wagons are given periodical preventive maintenance in order to keep them in good fettle and avoid failures/break down in service. Since its inception way back in 1853 Indian Railways has come up with 45 workshops in 17 zones which are large establishments employing thousands of people dedicated for the periodical overhauling (POH) of the rolling stock. Workshops on IR are energy intensive units involved in preventive maintenance of locomotives and rolling stock at prescribed intervals to upkeep their systems in safe working order till the next overhaul.

These workshops are being dynamically upgraded and modernized by providing latest technological inputs in order to reduce human intervention in maintenance and to improve the efficiency of the process and reliability of the rolling stock. The study focuses on two major Carriage Repair Workshops located in South India one at Hubli and the other in the city of Mysore which were established in 1885 and 1924 respectively. Both of these workshops are in the business of undertaking POH of Broad Gauge (BG) coaches apart for other allied activities. Pre Independence period coaches were fully wooden bodied and post independence steel bodied coaches were introduced by IR in collaboration with Swiss Car & Elevator Company in 1950's. Lately state of art stainless steel coaches have been introduced with technical support from M/s. Alsthom LHB (Linke Hoffman Bosch)

The study undertaken uncovers the flow process of coach POH activity, its energy requirements and various variable inputs involved. Indian Railways has a dedicated organization named Central Organization for Modernization of Workshops (COFMOW), an ISO 9001:2000 certified institution located at Delhi which is the nodal agency for procurement of globally best technologies to cater to the IR workshop requirements of machinery and plant. The high technology equipments adopted by workshops in the recent past include underwater oxy plasma profile cutting, inverter based welding machine, oxy LPG profile cutting machine, CNC machines for axle turning and wheel turning, variable frequency drive, electrical overhead cranes etc. Under Research Designs and Standards Organisation based at Lucknow, IR has Centre for Advanced Maintenance Technology (CAMTECH) which provides guidelines for maintenance of rolling stock and also has laid down guidelines in the form of BG coach maintenance manual.

Govt. of India, Ministry of Railways had appointed two committees under the leadership of eminent personalities to study the organisation and give their suggestions one for modernisation [5] and the other for improving the safety aspect of the Railways [6]. Both the committees in their report submitted during Feb 2012 have highlighted the scope for conservation of energy in the organisation and have asked to set aside Rs 1000 Crores towards the same. Suggestions have also been made to invest in in-house power generation so that dependency is reduced and the rail services are not affected.

Kirit S. Parikh et al. [7] in their paper "Projecting India's energy requirements for policy formulation" mention that energy policy has to be a long term perspective. They find that even after employing all domestic energy resources to their full potential, there will be a continued rise of import dependence. They state that energy efficiency emerges as a major option with potential to reduce energy requirements by as much as 17%.

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Todd Litman [8] in his paper" Evaluating rail travel benefits: a comment", mentions that high quality grade separated transit does reduce urban traffic congestion and the urban transit improvements can be cost effective investments when all economic impacts are considered.

T.V. Ramachandra and Shwetmala [9] in their paper "Emissions from India's transport sector" mention that globalization and liberalization policies of the government in 90's have increased the number of road vehicles nearly 92% from 1980-81 to 2003-04. They calculate and state that India's transport sector emits an estimated 258Tg of Co_2 of which 94% is contributed by road transport. IR has an important role for long journey movement of persons and freight. They mention that current energy consumption in IR is around 5% of total transport energy with 77% from diesel and balance from electricity.

The study of energy requirements of workshops of IR and the potential for conservation is comprehensively not undertaken as far as our knowledge goes as it involves two departments viz. Mechanical department for liquid, gaseous fuels and Electrical department for electricity consumption. Research studies in industries are not undertaken for inaccessibility of data moreover data is not available at times. This study is an attempt to study the energy issues duly considering data available for other sister workshops. Similar comprehensive studies are not undertaken but studies pertaining to electricity consumption and its conservation are undertaken by workshops and Indian Railway Institute for Electrical Engineering (IRIEEN) Nasik. Research Designs and Standards Organisation (RDSO) located at Lucknow does extensive work on traction energy be it electricity or diesel as it has state of art laboratories set up for the same.

2. OBJECTIVE AND SCOPE

The objective of the study is to understand the activities of railway coach repair workshops, the various energy inputs for undertaking the passenger coach maintenance activity, the present energy consumption pattern for the various activities viz. for periodical overhauling of coaches and various manufacturing activities in order to assess the energy conservation potential. All the forms of energy carriers used by the workshops have been considered for study viz. electricity, diesel and LPG. The electrical energy supplied by the Electrical Distributing companies and that generated in-house during power cuts has been compiled on a monthly basis for the five year term under study. Diesel consumed by internal and external transport vehicles and LPG used for cutting of plates and canteen too has been collected. Study correlates the output of the workshops to the energy inputs. Based on the study of the two workshops the critical areas having potential for energy conservation has to bring out duly considering the latest technological developments.

The study covers two major Carriage Repair Workshops located at Hubli and Mysore in the state of Karnataka which are mainly undertaking the periodical overhaul of Broad gauge passenger coaches. The study covers a time period of five calendar years from 2007 to 2011. The major activities of both the workshops have been accounted for and a common unit evolved based on the energy inputs and the allowed man-hours to compare the outputs of the two workshops with respect to their energy consumption. The study does take inputs from the visits to other railway workshops and interactions with their management. The energy audit reports of sister workshops are taken for reference and better understanding of the activities involved in coach maintenance.

3. METHODOLOGY

The two workshops have been personally visited for understanding their core activities. The time taken for various sub activities has been compiled and the major energy consuming devices identified. Interactions have been undertaken with the top management of both the workshops as regards their output and energy inputs. Interactions with the supervisors and staff using energy have been extensively undertaken. Various other workshops of similar nature located in other states have been visited to study their maintenance practices. The energy audit reports of workshops has been studied and discussed with the Divisional Electrical Engineers who also act as energy managers of both the workshops. Various new technologies commercially available as per websites of Bureau of Energy Efficiency Ministry of Power, Govt. of India and other manufactures web sites have been taken into consideration for suggesting technical alternatives.

4. DATA SOURCE

The various output of the workshops, the energy purchased from electricity distribution companies and the diesel used by the captive generation sets have been recorded and analysed. The data from the electricity bills of the two workshops, the log book of diesel generating (DG) sets, the outturn statement maintained by planning office have been recorded. An interaction with the Divisional Electrical Engineers (DEE) of both the workshops has brought out their vision for the future. The various sub activities, man hours required to undertake the same have been recorded. The energy bill also gives the breakup of fixed charges (Contract demand) and that of actual power consumed by these two workshops. The major activities involved in maintenance of coaches such as POH of AC and Non AC coaches, IOH of coaches and refurbishment of coaches have been studied with respect to man power utilization and man hours required to undertake the jobs in general. Similarly the manufacturing activities such as manufacturing of bogies, bolsters, BVZi brake vans and composite brake block manufacturing yield the following conversion factor.

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Various workshops over IR involved in coach POH located in Andhra Pradesh, West Bengal, Tamil Nadu, and Madhya Pradesh have been visited to study the maintenance practices adopted there. Discussions have been carried out with CAMTECH personnel regarding the requirements for POH of BG coaches as per maintenance manual issued by them. Written consent has been obtained from the workshop heads i.e. the Chief Workshop Managers to undertake the study of their respective workshop. The personal visit to Hubli workshop and Mysore workshops led to collection of the data for the period of five calendar years from 2007 to 2011 viz.

The three main energy carriers for both the workshops are Diesel, Electricity and LPG. Diesel is mainly consumed by both the workshops for Internal and external transport vehicles and also used for DG sets for power generation during power cuts by distribution companies. Electricity is the main energy carrier for all the electrical loads such as induction motors for machines, cranes, air compressor motor, lighting & ventilation loads and for welding plants.

BCG (LPG with additives) is used in UBLS in 19 kg cylinders for profile cutting (oxy fuel) of steel plates. Upon utilization the quantity of LPG in the cylinder reduces and so is its pressure. When the pressure drops below threshold pressure it is unable to be used in profile cutting machine but still about 10 - 15 % of LPG is left in the cylinder which is given to canteen for cooking purpose. Hence, UBLS canteen does not buy any separate LPG for food preparation which is not the case with MYSS. LPG is used in MYSS for three different activities one is for POH of coaches, secondly for composite brake stock manufacturing and thirdly domestic (14.2 kg) gas is used by canteen.

Table 1 "2011"- Energy consumed by UBLS and MYSS

Sl. No.	Type of Energy Carrier	Application	UBLS	MYSS
1	Diesel in liters	a. D. G. Set	11,000	15,600
		b. Transport vehicles	45,000	50,000
	Total Diesel in liters		**56,000**	**65,600**
2	**Electricity in kWh**	**Machines, Cranes**	**16,35,771**	**6,85,963**
3	LPG in kg	a. Coach POH b. Production c. Canteen	19380 16150 0	11,000 11,000 8,500
	Total LPG in Kgs		35,530	30,500
4	**Total Energy**	**GJ**	**9631**	**6385**

The allowed time in hours for all the activities in the workshops are arrived after conducting work study as per ILO guidelines. As the maintenance activity and allied activities involve various forms of energy, the conversion factor is evolved which does consider the allowed time and the various energy carriers involved. The general overhead electricity consumption towards supervision, administrative offices, general facilities viz. laboratory, canteen, illumination and ventilation throughout the workshops have been allotted towards coach POH activity as that is the core activity of both the workshops

Table 2 Conversion factor for major activities of Coach Repair Workshops

Sl. No	Activity	Conversion Factor	Allowed Time in Man Hours
1	POH of Non AC Coach	1	3300
2	POH of AC Coach	1.5	5000
3	IOH of Coach	0.1	380
4	Refurbishment of Coach	2	7000
5	Manufacturing of Bogies	0.5	500
6	Manufacturing of Brake Van	1.5	3500
7	Manufacturing of Bolster	0.1	175
8	Manufacturing of CBB	0.02	1.33

Table 3. Central Workshop Mysore Annual Output

Sl. No.	Activity	Output for the Calendar years in terms of Non AC Coach POH				
		2007	2008	2009	2010	2011
1	POH of Non AC BG Coach	702	724	738	647	591
2	POH of AC BG Coach	147	180	168	195	180
3	IOH of BG Coach	0	0	34	57	55
4	Refurbishment of Coach	0	0	0	40	92
5	Mfg of Toy Train	0	0	5	10	5
6	Mfg of Comp. Brake Blocks	96	98	104	122	126
Total Annual output		945	1002	1049	1071	1049
Energy Consumed in '000 kWh		1049	924	919	937	734
Specific Energy Consumption		1110	922	876	875	700

Output of MYSS for five year term from 2007-11 has been shown in table above. It can be seen from the table that coach POH especially non AC coach POH is the core activity comprising 56% of the annual output. Ac coach POH comprises of 17% of the annual activity and in all POH of coach has the share of 73% in the total annual activity. Hence the study takes the POH of non AC coach as a benchmark to compare the two coach repair workshops.

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Table 4. Carriage Repair Workshop Hubli (UBLS)

Sl. No.	Activity	Output for the Calendar years in terms of non AC Coach POH				
		2007	2008	2009	2010	2011
1	POH of Non AC BG Coach	1007	1078	895	697	654
2	POH of AC BG Coach	150	180	155	186	136
3	IOH of BG Coach	0	0	34	58	69
4	Refurbishment of Coach	0	0	186	260	230
5	Mfg of ICF Bogies	654	872	1204	1123	1503
6	Mfg of Bolsters	61	164	256	204	162
7	Mfg of BVZi Brake Vans	153	216	261	271	266
Total Annual output		2025	2510	2991	2799	3020
Total Electricity Consumed in '000 kWh		1560	1899	1863	1794	1669
Specific Energy Consumption / Coach POH		**770**	**757**	**623**	**641**	**553**

Table 4 above depicts the major activities undertaken by Carriage Repair Workshops annually from 2007 to 2011. It is observed that POH of Coaches is the major activity followed by manufacturing of ICF bogies. The share of coach POH is fallen from 57% in 2007 due to extension of POH periodicity from 12 months to 18 months by introduction of high technology components.

Hence manpower and other resources are being effectively utilised to improve the share of allied activities. The specific electricity consumed for POH of Non AC Coach POH has shown gradual decline from 770 units to 553 units due to incorporating energy conservation measures in a sustained manner.

Table 5 Installed load at MYSS during 2011

Sl. No	Description of Load	Qty in No's	Total Load in kW
1	Machineries	120	2900
2	Welding plants	105	1700
3	EOT Cranes	13	316
4	Air Compressors	8	160
5	Electrical Hoists		35
6	Lighting Load		55
7	AC Plant		21
	Total		5187

5. RESULTS AND DISCUSSIONS

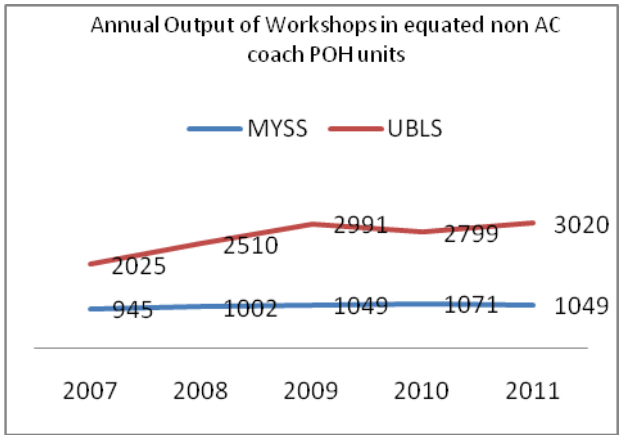

Fig 1 Annual Output of UBLS and MYSS

Fig 1 above shows that Hubli workshops overall output is more than double of Mysore workshops consistently as the number of coach overhauled is more and also UBLS undertakes fabrication of bogies and brake vans. As far as manpower is concerned UBLS has more than 3000 staff when compared to 1800 staff of MYSS. Railway Board to ensure better availability of coaches for passenger traffic decided to extend the periodicity to undertake POH from 12 months to 18 months in the year 2009. There is provision of IOH for the bogies in-between two successive POH at 9 months interval. Hence there is a gradual decline in the output of coach workshops after this development as seen from the figure above.

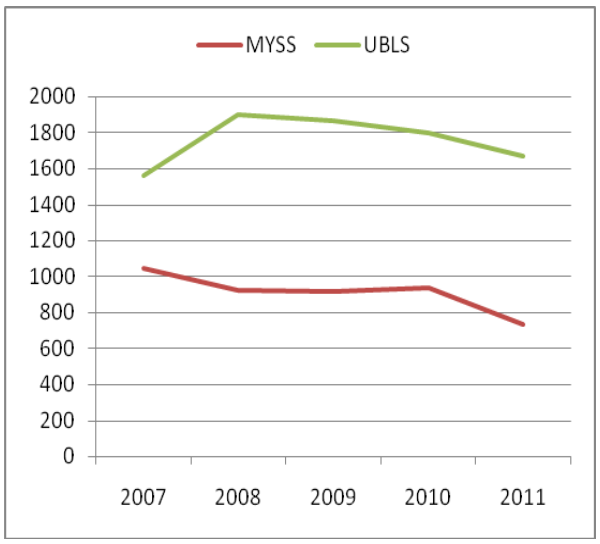

Fig 2 Annual Electricity Consumption in '000 kWh

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Fig. 2 above shows that during the year 2008 Hubli Workshops annual electrical energy consumption suddenly increased from 15 lakh units to 19 lakh units after the commissioning of axle box cleaning plant of 350 kVA capacity. There after we see a gradual decline in the total energy consumed by Hubli Workshops and so is the case with Mysore workshops due to implementation of various energy conservation measures by both the workshops. The various energy conservation measures include rationalization of power distribution system inside the workshops, optimum loading of power transformers, regenerative testing of alternators and batteries, high efficacy illumination equipment like T5 lamps , Metal halide lamps retro fitment, installation of power savers for AC welding plants etc.

Fig 3: Specific electricity consumption in kWh per non AC coach POH

Figure 2 clearly indicates that over a period of five years from 2007 to 2011 the Specific energy intensity ie energy used for undertaking coach POH and other fabrication activities is declining. Mysore Workshops consumes slightly more energy when compared to that of Hubli workshops for all the period under study. This is mainly because of use of dated technology centralized compressor of 95 kW capacity operated for almost five hours a day when compared to smaller decenralised compressors used by UBLS. MYSS also continues to use transformer type welding plants and the welding plants of MYSS have not been fitted with energy saving devices as carried out by UBLS on both transformer type and rectifier type welding machines.

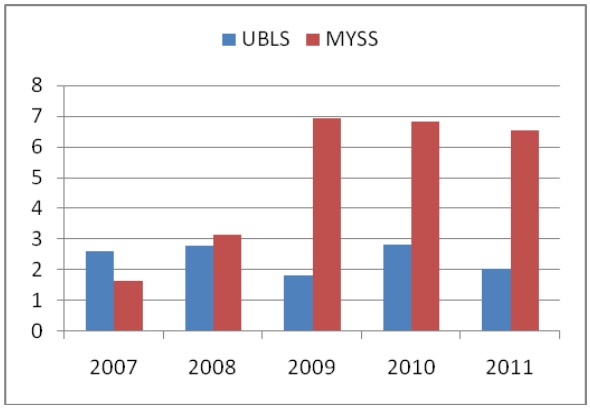

Fig 4 Percentage of power generated by DG sets

The percentage of power generated by DG sets of MYSS is consistently higher than UBLS for four years since 2008 and is of the order of 6 to 7 % of the total power consumed. This is quite expensive as the cost of diesel alone towards power generated by DG sets hovers between Rs 11 to Rs 14 per unit as seen from figure 5 below as against Rs 5 per unit supplied by the Electricity distribution companies. Adding other operation, maintenance and depreciation costs to the fuel costs shall shoot up the cost of power generated to four times that of brought out power. Hence both the workshops can seek dedicated express feeder to ensure uninterupted power supply to avoid running of generator as the workshops are meant for providing essential services to the nation apart from avoiding local pollution.

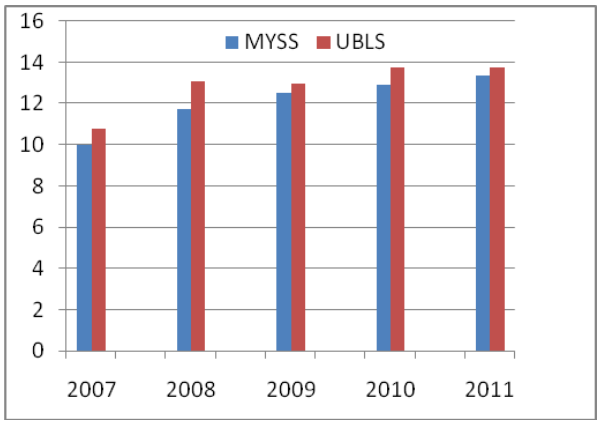

Fig 5 DG Sets Fuel Cost per Unit in Indian Rupees

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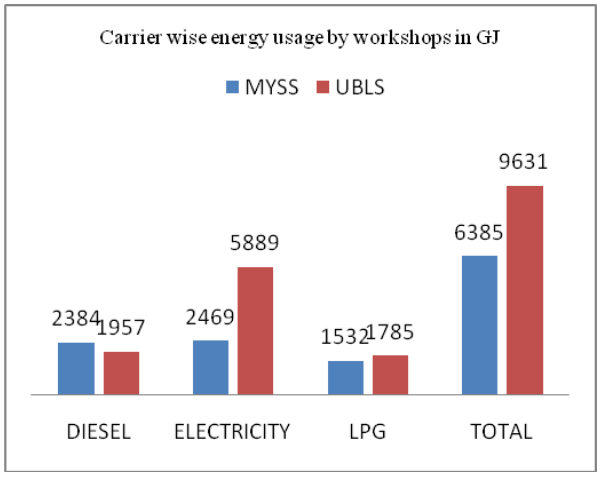

Fig 6 Major Energy Carriers and their share for 2011

The major energy carriers of workshop are depicted in fig 6 above. Electricity is the major carrier in terms of energy units (GJ) followed by diesel and LPG in that order. Hence focus is given for conserving electricity and as seen from fig 3 above the conservation potential of 1, 00,000 units is there by the smaller workshop considering an annual outturn of 680 coach units.

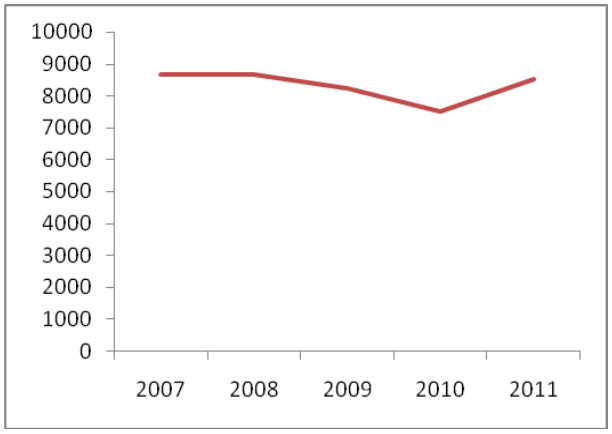

Figure 7 Consumption of LPG by MYSS canteen in Kgs

The consumption of Bharat Cutting Gas (BCG) is used extensively for profile cutting of steel plates in UBLS. The usage BCG has led to fall in Dissolved Acetylene (DA) usage as BCG is able to cater to the requirement of cutting 22mm plates successfully. The cost of cutting MS plates was higher with DA when compared with BCG and as such the transition was taken for the energy source. The consumption of DA by UBLS during 2007-08 was 4688 Cylinders with an average of 390 cylinders per month.

MYSS continues to buy 14.2 kg subsidized LPG for its canteen requirements as per fig 7 above. UBLS has discontinued the practice of buying LPG for its canteen requirements and the left over BCG with reduced pressure which is unable to be used for profile cutting of plates is being utilised.

On an average 150 staff food requirements are being met by the canteens and as such it would be advisable to try out the strategy of UBLS in MYSS to save on LPG consumption for canteen purpose.

6. SUMMARY AND CONCLUSIONS

The study concludes that Indian Railways is keeping pace with the change in times and change in technology and is adopting the most efficient technologies in the system of coach maintenance to reduce its carbon footprint and conserve precious resources. Both the workshops studied have streamlined the POH of coach activity to achieve better flow and reduced energy inputs to undertake the work which is of a continual nature. The cost of power generated using diesel by the captive diesel generator sets is higher when compared to that of power supplied by electricity distribution companies.

The study finds that there is scope of conservation in the workshops as there is variation in energy consumed per unit of output between the two workshops undertaken for study. The Main Energy Consuming devices in Workshops being Compressors, Welding plants, Electrical Overhead Traversing Cranes new technologies can be implemented in a phased manner. The smaller workshop having specific energy consumption of 700 kWh per equated Non AC coach POH can bring it down to 553 kWh by adopting better technologies and electricity management principles which gives way to conserve 15% electricity per annum. To achieve this workshop has to change over from dated technology equipments such as reciprocating air compressors, transformer welding to rotary screw type compressors and inverter based welding plants to conserve energy.

7. ACKNOWLEDGEMENTS

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NOMENCLATURE

SYMBOLS

IR - Indian Railways
ILO – International Labour Organisation
UBLS – Carriage Repair Workshop – Hubli (SWR)
MYSS – Central Workshops, Mysore (SWR)
ICF – Integral Coach Factory
LPG – Liquefied Petroleum Gas
DA – Dissolved Acetylene
KWh – Kilo watt hour
KW – Kilo Watt
MW – Mega Watt
GJ - Giga Joules
BG – Broad Gauge
BVZi – Brake Van High Speed for Goods train
POH – Periodical Overhaul
IOH – Intermediate Overhaul
AC – Air Conditioned
Non AC – Non Air Conditioned
EOT – Electrical Overhead Traversing
RDSO – Research Designs and Standards Organisation
COFMOW – Central Organisation for Modernisation of Workshops
SWR – South Western Railways
HESCOM – Hubli Electricity Supply Company
CHESCOM – Chamundeshwari Electricity Supply Company

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Suresh D. Mane took voluntary retirement from Indian Railways (IR) where he last worked as Asst. Divisional Mechanical Engineer (Diesel) to join as Assistant Professor at Department of Mechanical Engineering at Shaikh College of Engineering, Belgaum, Karnataka, India. He has 22 years of experience with IR. He is a Certified Energy Auditor from Bureau of Energy Efficiency, Govt. of India. He is persuing research in the field of Energy Management. He has 2 publications in international journals and 4 articles in Indian Railways Magazine apart from 8 papers in national and international conferences.

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