The International Journal of Engineering And Science (IJES)
||Volume|| 1 ||Issue|| 2 ||Pages|| 324-331 ||2012||
ISSN: 2319 – 1813 ISBN: 2319 – 1805

Renewable Energy Technologies for Carriage Repair Shops: A Case Study of Two Workshops

Suresh D. Mane[1] and N. Nagesha[2],
1. Research Scholar, Asst. Divisional Mechanical Engineer, S.W. Railway (Rtd.)
Dept. of Industrial and Production Engg. UBDT College of Engineering,
Davangere Karnataka, India. 577 004. Ph +91-9448433574
2. Associate Professor & Chairman
Dept. of Industrial and Production Engg., UBDT College of Engineering,
Davangere Karnataka, India. 577 004.

----------ABSTRACT----------
Expert group for modernization of Indian Railways have highlighted the need for Rs.1000 crores investment in renewable energy projects through Private Public Participation initiative in their report submitted to the Ministry during Feb 2012. An additional Rs.1000 crores is to be invested in energy saving projects along with another Rs.1000 crores in captive power generation, in view of increase in power demand. This clearly indicates the ample scope for adopting renewable energy technologies and energy conservation in Indian Railways in the days to come. Using renewable energy assumes significance due to dwindling fossil fuels and the environmental advantages associated with the renewable. Considering the above facts a study was undertaken at two coach repair workshops of Indian Railways to find out the consumption of various forms of energy and the areas which can use renewable energy technologies. The study finds out that Indian Railway Workshops have taken the lead to implement renewable energy technologies in various forms viz solar photovoltaic's for illumination, solar thermal units for hot water requirements and is planning to set up offsite wind power plants to harness wind energy and meet the electrical energy requirements of workshops. Except for inductive loads solar technologies has been successfully implemented, operated and maintained. All out efforts under the direction of Railway Board, RDSO and Zonal headquarters are underway and shall improve the share of renewable in years to come.

Keywords *– Carriage Repair Workshops, Indian Railways, Renewable Energy Technologies, Energy consumption, Energy Conservation*

Date of Submission: 17, December, 2012 ⟺ Date of Publication: 30, December 2012

I. Introduction

Energy is an important resource for economic growth and human comfort and its need over the years has increased substantially. The need for energy is going to increase further due to increased population and the comfort levels of human beings, be it in the form of transportation, accommodation, life style and the overall growth in infrastructure.

The population of this world is at 7.016 billion as on May 2012 and the total energy consumption is 13000 MTO (Million Tonne Oil Equivalent). This large amount of energy is used mainly by industries, residences/offices/commercial establishments, agriculture, and transport. At the national level, as per Ministry of Petroleum and Natural Gas projections, India has total reserves of 757 million metric tons of crude oil and 1241 billion cubic meters of natural gas as on April 2011 with corresponding crude oil production of 37.71 million metric ton, natural gas at 52.22 billion cubic meters and consumption of petroleum products at 141 million metric ton. In fact, India is quite aggressive in exploiting its oil and natural gas resources to meet the ever growing energy needs of its population but its oil production has remained stagnant for the past one decade and as such the percentage of net imports has increased to a present level of 80%. During 2011-12 India imported 25.5 million tons of crude oil costing Rs. 4, 88,550 Crores towards imports. India is thus an energy deficit nation and has to focus on both supply side as well as demand side management to manage its energy requirements. Indian annual energy deficit is 10.3% or 96,367 Million Units and peak deficit is 12.9% or 17,517 MW.

Being a major energy consumer, Indian Railways (IR) is the backbone of India's transport infrastructure and nation's largest transporter connecting, integrating the country and moving men and materials from one place to another. It moves 2.2 million ton of freight and 220 million passengers on a day to day basis 24 x 7 for all 365 days. 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 and speedy delivery in short circles, especially for lower volume of consignment. Indian Railway operates more than 9000 passenger trains and totally 14000 trains on its daily operation wherein the local train in Mumbai, Chennai and Kolkata contribute to the larger chunk of passenger trains and commuters. IR consumes 2.5 % of the Country's total electricity.

IR vide vision document 2020 has initiated steps to reduce its carbon foot prints and expects upto 15% energy saving through various measures. The vision document highlights that at least 10% of energy used by IR should be sourced from renewable sources such as solar power and biomass. Procurement of 3 stars and above higher rated products is mooted for energy efficiency. Massive plantation drive along tracks, in colonies and even grass surfing is being used as a protective erosion measure on the slopes along the tracks. Since 2011, United Nations Development Programme (UNDP) in partnership with Ministry of Railways, Government of India, is making efforts to improve energy efficiency in the IR system by focusing on capacity development, technical training, implementation of energy efficient technologies and sharing knowledge on best practices. IR has already set up an organization Indian Railway Organization for Alternate Fuels (IROAF) which is taking steps to introduce cleaner fuels for diesel loco hauling such as bio-diesel for locomotives and Compressed Natural Gas (CNG) for Diesel Electrical Multiple Units and Diesel Power cars.

The Railways has a fleet of 9213 locomotives, 53220 coaches, 6493 other coaching vehicles and 229381 wagons. IR consumed 15509 Million kWh of electricity and 2500 million liters of diesel during 2009-10, for its operations involving traction and non traction applications. Energy costs amounts to 24% of total operating expenses of Indian Railways and with Rs. 18000 Crores accounting for fuel expenses. Indian Railways is India's largest energy consumer, be it in the form of electricity or diesel. 87% of the energy consumed by Railways is utilized for traction purposes and the rest for non traction application. 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 spread over 17 zones. Next to traction, workshops consume the highest amount of energy in the form of electricity whereas diesel sheds consume diesel for maintenance of locomotives and for conducting various tests for checking the health of the locomotives.

Carriage Repair Workshops Hubli under South Western Railway (SWR) constituted in 1885 is one of the major workshops in IR employing 3400 persons catering to Periodic Overhauling (POH) of 75 Broad Gauge (BG) coaches per month (both Air conditioned (AC) and non AC coaches and fabricating coach bogies of different designs. Lately, Intermediate Overhaul (IOH) of coaches is being undertaken at 9 months interval. POH of coaches is undertaken at an interval of 18 months and first POH is undertaken after two years of manufacture and IOH is undertaken in between two successive POH to keep the bogie, its components like brake system in good fettle. The average cycle time for undertaking POH of BG coaches is 15 days and it takes 3500 man hours for Non AC coach and 5500 hours for AC coach. Bogies are manufactured of various types for BG coaching stock including Electrical Multiple Units (EMU) coaches for suburban trains. The average man hours required for fabrication varies from 400 to 600 and mainly includes profile cutting of steel plates and welding the same to get the desired shape. This workshop has an installed load of 9500 KVA, peak load of 1300 KVA and consumes 1, 30,000 kWh of electric power per month. Furnace oil is consumed by normalizing and other heating furnaces to the tune of 5000 litres per month. Industrial gases viz., Argo shield gas, LPG, Oxygen are also consumed mainly for oxy gas profile cutting and welding of steel plates.

Maintenance of BG coaches is undertaken as per RDSO (Research Design and Standards Organization) guidelines in the form of BG coach maintenance manual issued by Centre for advanced Maintenance Technology (CAMTECH), Gwalior and other technical specifications issued from time to time. Fabrication of bogies is undertaken as per standard training issued by Integrated Coach Factory (ICF) Chennai, along with latest modifications. Steel plates for manufacturing of bogies are mainly supplied by Steel Authority of India Limited (SAIL) and are supplied by the consignees like ICF, Rail coach Factory (RCF) to these shops. Energy consumed by CRWH towards POH of BG coaches has been recorded as 750 units for 2009-10, 1040 units for 2010-11 and 984 units for 2011-12 which constitutes about 1% of the cost of POH of the coach.

IR has 45 workshops which are in the business of carrying out preventive maintenance i.e., Periodical Overhaul (POH) of locomotives, coaches and wagons each employing thousands of employees. POH is essentially carried out to ensure safe running of the coaches and is closely monitored and expedited. The current study is undertaken in two such workshops located in the State of Karnataka; Carriage Repair Workshop at Hubli and Central Workshop at Mysore are serving the nation since several decades. As these workshops were started way back in 1885 and 1926 respectively, the technology adopted also requires modernization. Both these workshops have identified investment opportunities for technological up-gradation and are also executing the same duly incorporating energy efficiency and renewable energy technologies appropriately.

These coach workshops earlier had to attend to wooden bodied coaches but presently attending to steel bodied coaches and are now gearing up to attend state of art stainless steel bodied coaches. Both the workshops are spread over large geographical area and are divided into large number of shops and sections which have a variety of plant & machinery, equipment required for the process of coach maintenance. The shops of coach workshops include Carriage Lift Shop, Body Repair Shop, Bogie Repair Shop, Machine Shop, Wheel Shop, Spring Shop, Welding Shop, Paint Shop, etc., which cater to the various requirements. To coordinate the shops, offices are housed in administration building comprising personnel branch, accounts branch, and other offices.

II. Literature Survey

Kirit S. Parikh et al. 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%.
Todd Litman 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 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 above papers highlight that energy efficiency measures can reduce energy consumption and as railways is a environment friendly mode of transport it is more worthwhile to undertake the study of its constituents.

III. Methodology

The two workshops have been visited personally to collect the data. Energy experts from the two workshops viz the Divisional Electrical Engineers have been approached for discussions and their observations, action plans and suggestions noted down. The energy requirement of the two workshops, the coach POH process has been studied in detail to evolve a energy flow process sheet. The energy requirements have been quantified annually for five years commencing 2007 till 2011 for all forms of energy carriers. The various renewable energy technologies adopted have been discussed and the feasible ones have been enumerated.

Carriage Repair Workshop – Major Energy Carriers

- Electrical Energy: For Illumination, Air Circulation, Crane Operation, Machine-Tools Operation, Battery Operated Truck Operation, Welding Equipment, Heating Ovens etc.
- Fuels: High Speed Diesel is used for Forklift Trucks, Locomotive used for coach movement activities and Diesel Generating Sets.
- Furnace Oil is used for Furnaces.

Green Measures implemented by Carriage Repair workshops

- Entire administration building power requirement at CRWH is being met with solar Photo Voltaic (PV) system installed on Training Centre roof top with battery back up.
- Stand alone solar street lights are being procured for fitment on pathways and roads.
- Entire water used for cleaning of coaches is collected, filtered, treated and reused for coach cleaning activity.
- Rain water is harvested, collected, stored and reused.
- Proposal is made to install 10 MW Capacity wind power plant to cater to all the power requirement of the workshop and Diesel Shed, Hubli. A smaller unit of 5.2 kW power wind turbine is being procured

for installation over Laboratory building to cater to illumination requirement in conjunction with solar PV system. Thus, the current study found that IR workshops are in the forefront of implementing green technologies by introducing renewable energy system and technology up-gradation in their workshops.

Major Energy Consuming Devices Used By Carriage Repair Workshops

1. **Internal transport of coach from one shop to another**
   - Shunting loco having Diesel Engine of 1200 hp.
   - Traverser having electrically operated (Electric Induction Motor)

2. **Internal transport of sub assemblies from coach to shop and back.**
   - Forklift trucks with Diesel Engine
   - Battery Operated Trucks (BOT) using Electricity for recharging.
   - Cranes and Hoists: Electrical Overhead Traversing (EOT) with Electrical motors

3. **Machines used during POH**
   - Wheel lathe for coach wheel turning, Vertical turret lathe for Wheel disc boring Axle turning lathe for axle machining, Radial Drilling machine
   - Centre lathe for manufacturing duplicates, machining buffer plate
   - Spring testing machine, hyd. Press,
   - Hand held portable grinding machine, drilling machine
   - Sewing machine for upholstery stitching

4. **Utilities**
   - Gas cutting equipment – Body repair, floor repair
   - Welding equipment having Transformer AC Sets, DC Sets having Rectifier, Inverter
   - Air Compressors for compressed air facility and for spray painting
   - Water jet cleaning machine – Washing of Coach interior and exterior
   - Water pump for Hydraulic testing of water tanks
   - Lights for Illumination and Fans for ventilation

5. **Non Destructive Testing (NDT)**
   - Magnetic Particle Test (MPT) of hangers, Anchor links (welded), Equalizing stays
   - Zyglow test of springs and bearings.
   - Dye Penetrant Test
   - Chalk test of buffer casing
   - Ultrasonic test of axles

6. **Electrical Shops: Electrical Millwright (EMS) /Electrical Repair Shop (ERS)/AC Shop /TLW Train Lighting Shop**
   - Testing of Alternators for AC and Non AC Coaches
   - Charging/Discharging & Capacity testing of batteries
   - Demineralisation plant
   - Testing of Rectifier and Regulating units
   - Testing of Compressors for Air Conditioners

RENEWABLE ENERGY TECHNOLOGIES PROPOSED

- **S**olar water heating arrangements for canteen as well as axle box cleaning plant.
- Solar PV for Administration Building 5 kW Peak
- Light pipe for shops not having enough daylight to harness natural light.
- Wind mill to be used for Illumination purpose
- Use of Biodiesel for Captive power gensets, diesel engine operated fork lift trucks and locomotive used for shunting of coaches.

The workshop has staff strength of 3400 who work in three shifts to maintain the coaches. Out of them, 200 staff has lunch everyday which comprises chapattis, dal, vegetables, and rice. Presently residual LPG after profile cutting of steel plates is being utilized for steam preparation for cooking of rice and idly. It is

proposed to install a solar water heater for canteen so that hot water can be used for cooking as well as dishwashing.

Hubli has a Carriage Repair Workshop and a Diesel Locomotive Shed along with a Railway junction, Divisional Office and Railway Colonies, which are major energy consumers. The present arrangement is South Western Railway purchases power from Hubli Electricity Supply Company (HESCOM) and then it is distributed to shed, workshop, colony, station. A proposal has been made for installation of 2.1 MW wind power generator at a suitable place either near Gadag or Chitradurga where adequate wind speeds is available throughout the year. Once installed by external agency the power will be banked and wheeled to cater to the needs of Hubli workshop and Diesel Loco shed. Excess energy may be sold to HESCOM.

The staff in the workshop is working in shifts and hence they return home after 10:00 pm and 1:00 am after the second and night shifts are completed respectively. The cycle stand needs to be kept illuminated throughout the night to facilitate the staff to pick up and keep their vehicles. Presently the light fittings include sodium vapour lamps and metal halide lamps which use electricity. It is proposed to replace the same with solar stand above street lights with Light Emitting Diode (LED) bulbs.

Solar PV Plant for Illumination

The administrative building at CRWs Hubli houses the chambers of all officers of Mechanical, Electrical, Personnel and Accounts departments and their offices. The energy is mainly used for illumination and fans. All the old obsolete light fittings have been replaced by new generation T5 lamps and are now being fed by a 5 kWp Solar PV module. The solar PV modules are kept over the roof top of the training centre so that they are exposed to sun and the power generated is stored in lead acid batteries bank from where it is fed to the lights in the administrative building.

Building services systems performance is measured using building energy performance index (BEPI) = (Annual energy consumed in building)/(Total built up area of building). BEPI depends on building type, occupancy, climate type and is least for moderate climate places like Mysore and Hubli.

.

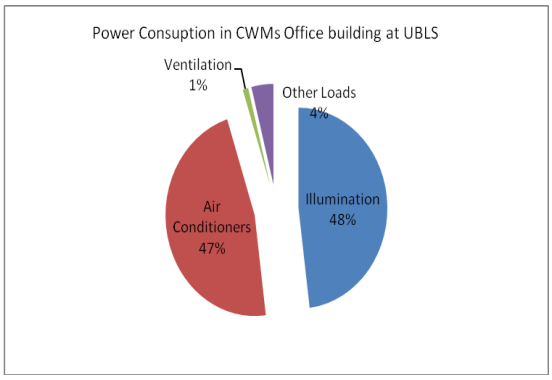

Fig 1 Pie Chart of various loads in Administrative Office

To begin with, introduction of solar PV system in the workshops as a pilot project has been designed and executed at CRW workshop, Hubli. Considering the demands of various offices and shops/sections, it was decided to install the solar plant to cater to the illumination load of the administrative building. To improve the BEPI action plan was drawn to improve the illumination component by introducing renewable energy as the illumination load is fairly constant and the variations are minimal, when compared to the air conditioning load.
The demand of the building which houses all the chambers of officers and their respective offices were studied. Lamps were selected based on the basis of efficacy in lumens per watt and thus old generation T12 tube lights with aluminum and copper chokes were removed. Subsequently, new generation T5 tube lights of 28 W capacity having 90-105 lumens per watt efficacy were retrofitted to allow even and adequate illumination in all chambers and offices.
The design of plant is as follows:

Lighting load	= 100 x 30 W	= 3000 watts/hour	
Total duration for Lighting	= 8 hours		
Total load	= 3000 x 8	= 24000 watt hours =	24 KWh.

A 5 KW peak solar PV module was brought and placed on roof top to ensure adequate solar radiation falls on the same at all times without any obstruction. Railway AC coach inverter 2.5 KVA (3 nos.) and batteries valve

regulated lead acid batteries of 1100 Ampere Hours capacity (19 nos./set three sets) are kept to convert the power and charge/store the power in batteries.

Light Pipe

To harness day light in enclosed rooms with little exposure it was decided to call for external agencies to install light pipes in trimming shop which caters to the upkeep of upholstery. The entire shop was divided and fitment is planned over the existing roofing by cutting open the required portions and fixing the light pipe dome collectors and sealing the adjoining periphery to avoid water ingress. Thus, high wattage lamps such as metal halide lamps have been put off and only light pipes along with T5 lamps are being used regularly.

Rain water harnessing and reuse of coach washing water

Both CRWH and CWM have taken the initiative to harness rain water and also reuse the water utilized for coach washing by proper treatment. In CWM the rain water collected is used to recharge the bore well and a Treatment Plant is set-up to treat the water which is reused for washing of coaches or for gardening purpose. In CRWH a huge 60 lakh litres capacity ground level storage tank is provided and the daily consumption of water is to the tune of 1.2 lakh litres. Necessary provision for Settling, Aeration, Coagulation, Filtering are provided to ensure better quality of treated water.

Use of Biodiesel in diesel engines

Indian Railways has set up a biodiesel production unit at Loco Workshops Perambur in Chennai which is successfully manufacturing biodiesel for the past 8 years. Similar plants are being established at Raipur in Chattisgarh and Tondiarpet near Chennai. Biodiesel is being used in blends of B5, B10 and B20 for diesel engines of transport vehicles and locomotives. CRWH and CWM both use a locomotive for shunting operation i.e. to move the coach from one place to another within the shops and also to get in the coaches from yard and release the coach to division after POH. These locomotives have 2600 hp diesel engines and are mostly underutilized. Similarly both these workshops invariably use diesel engine operated fork lift trucks as the components handled are quite heavy. Workshops do have stand by captive power generation diesel engine operated gensets which are pressed into service during power cuts. As already Biodiesel is successfully introduced it can also be tried out in both of these workshops in days to come.

IV RESULTS AND DISCUSSIONS

The study brings out the out turn of the two workshops on common units for comparison and finds that the bigger workshop UBLS has higher outturn consistently over the five year period under study as it has larger manpower and resources. The outturn has stabalised since 2009 when Railway Board implemented the policy of POH after 18 months of service as against the earlier policy of POH at an interval of 12 months. This far reaching decision certainly reduces the energy requirements and increases the availability of the coaching stock for hauling traffic.

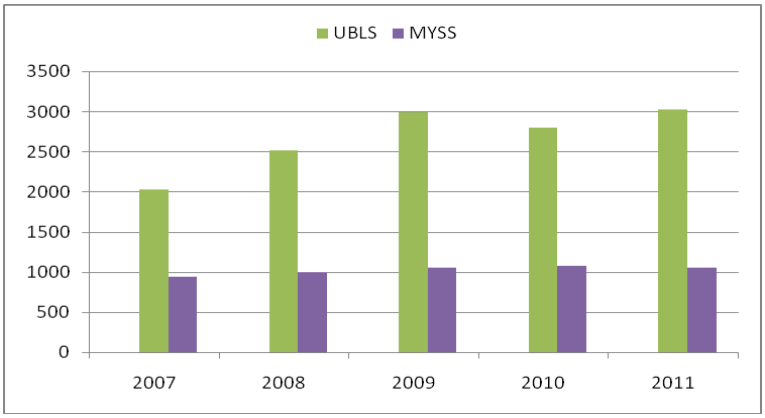

Fig 2 Annual Output of UBLS and MYSS in Equated Non AC Coach POH units

Table 1 Annual energy consumption pattern of both the workshops for the year 2011

COMMON UNITS GJ

SL	ENERGY	APPLICATION	CRWH	CWM	CRWH	CWM
1	DIESEL	D.G.SET	11000 LTRS	15600 LTRS	1957	2384
		TRANSPORT VEHICLES	42000 LTRS	50000 LTRS		
		TOTAL	53000 LTRS	65600 LTRS		
2	ELECTRICITY		16,35,771 kWh	6,85,963 kWh	5889	2469
3	LPG	COACH POH	19380 KG	11000 KG	1785	1532
		PRODUCTION	16150 KG	11000 KG		
		CANTEEN	0	8500 KG		
		TOTAL LPG IN KGS	35530	30500		
	TOTAL GJ				**9631**	**6385**

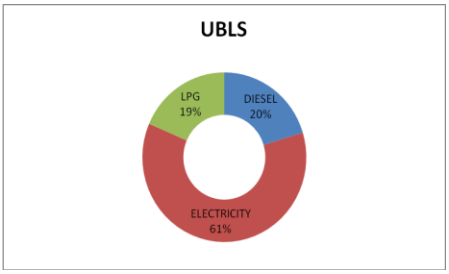

Fig 3 Share of different forms of energy consumed by CRWH during 2011 (GJ)

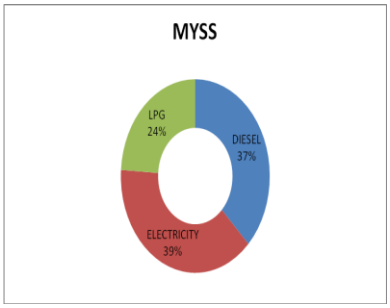

Fig 4 Share of different forms of energy consumed by CWM during 2011 (GJ)

The figures above clearly indicate that electricity is the major energy carrier for both the workshops followed by diesel and LPG. Hence efforts can be made to switch over to renewable based on the feasibility of application.

V Conclusion

IR has taken the lead to go green and hence encouraged all its units to reduce the carbon foot prints in a phased manner. The current study is focused on two IR workshops to study the energy consumption and suggest ways and means of adopting renewable energy to make IR more environment friendly. While CRWH has already initiated a few steps in this direction, CWM is planning to introduce the same in days to come. CWM is certified for Environment management system ISO -14001 which can be replicated in CRWH as it leads to conserving precious resources. Various energy saving options and ways of achieving the same are discussed. In Illumination, Lighting Controls can be of great help to reduce the power consumption through the use of controllers such as timers, lux level sensors, motion sensors and occupancy sensors. These sensors being economical can be easily fitted to conserve the precious energy. Biodiesel option for diesel engines of fork lift trucks, locomotive used for shunting operations and stand by gensets will reduce the local environmental pollution and reduce the crude oil imports. Measures to save energy, improve utilization efficiency and adoption of renewable energy etc., can go a long way in the sustainable development of this vital transportation sector of Indian economy.

VI Acknowledgement

Authors acknowledge with deep appreciation and gratitude the Chief Workshop Manager of Carriage Repair Workshop, Hubli and Central Workshop, Mysore for permitting to undertake the study in their respective

workshops and for their invaluable guidance throughout. Special thanks are due to Divisional Electrical Engineers of both the workshops for their immense contribution in guiding and also in discussions on the development on energy front. Thanks are due to all the Officers, Supervisors and staff of the two workshops for their contribution and co-operation in conducting the study.

NOMENCLATURE

POH	- Periodical overhaul,
IOH	- Intermediate Overhaul
CRW	- Carriage Repair Workshop Hubli
CWM	- Central workshops Mysore
IR	- Indian Railways
AC	- Air Conditioned
CAMTECH	- Centre for Advanced Maintenance Technology
RDSO	- Research Designs and Standards Organisation
ICF	- Integral Coach Factory
RCF	- Rail Coach Factory
BEPI	- Building Energy Performance Index
ETP	- Effluent Treatment Plant
Ltr	- Litres

References

[1]. Basic Statistics on Petroleum and Natural gas , 2010-11 Oct 2011 (Ministry of Petroleum & Natural Gas, Government of India)
[2]. Railways Vision Document 2020 (Dec 2009) pp. IV and V
[3]. www.in.undp.org/content/india/en/home/operation/projects/environment and energy/improving energy efficiency in the Indian railway system.
[4]. Indian Railways Yearbook2010-11/ keystatistics.pdf
[5]. Bureau of Energy Efficiency Book 1 chapter 9 pp. 210
[6]. Standard Note of Carriage Repair Workshop Hubli Jan 2012 pp. 1 to 8
[7]. Report of the Expert Group for Modernization of Indian Railways, Govt. of India, Feb 2012 Annex V
[8]. Report on High Level Safety Review Committee, Govt. of India Feb 2012 pp. 82 to 88.
[9]. GyanSukh Indian Railways Institute of Electrical Engineering (IREEN) Nasik Vol. 2 No 6 pp. 3
[10]. Standard Note of Central Workshop Mysore 2012 pp. 3 to 9
[11]. Sharad Saxena "Individual Study Report on "Renewable Energy Strategies for the Indian Railways"
[12]. Wolfgang Pfaffenberger, Karin Jahn, Marta Djourdjin- Bericth, "Renewable energies- Environmental benefits, economic growth and job creation – Case study paper 2006
[13]. Chetan Singh Solanki,"Renewable Energy Technologies- A Practical guide" PHI-2008 pp.3-8
[14]. Kirit S. Parikh et al., "Projecting India's energy requirements for policy formulation" Energy 34(2009) pp 928-941
[15]. Todd Litman," Evaluating rail transit benefits: A comment", Transport Policy 14 (2007) pp 94-97
[16]. T.V. Ramachandra and Shwetmala,"Emissions from India's Transport Sector- State wise Synthesis", Atmospheric Environment 43(2009) pp 5510-5517
[17]. Ravi S. Kochak, "Future of Energy and Transport in India", IRIMEE Jyoti (2012) Vol. 4, Issue 4 pp. 20
[18]. Detailed Energy Audit Report of Carriage Repair Shop, South Central Railway, Tirupati
[19]. Energy audit report of Eastern Railway Kancharapara Workshop, West Bengal.
[20]. TERI, Handbook on Energy Audit and Environment Management