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Energy Audit and Renewable Energy System-A Review

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ABSTRACT- Energy conserved is energy generated.Energyplaysapivotalroleinourlife.Thereq uisitefor energy is soaring. The intensifying demand canbe met either by furthering the energy generationorbyconservingtheusageofenergy.Genera tionofenergyisanexpensiveaffair;henceitisveryimpo rtanttoconserveenergy.Electricalenergyaudit is the process of examining the patterns inconsumptionofelectricitytodiscoveropportunitiest oconserveenergy.Energyauditisalabor-intensivetask;therefore,automationisnecessary.The EnergyAuditandRenewableEnergySystem(EARES) aims at introducing automation inthe process of energy audit and implementation ofdistributedgenerationofenergy.EAREShelpsin establishing a better understanding of electricalenergy usage tendencies and also create awarenessaboutconservationofelectricalenergy.
Keywords-EnergyAudit,RenewableEnergy andEnergy Conservation.

I. INTRODUCTION

AccordingtothelateststatisticsIndiafacesab aseloadenergydeficitof0.5%andpeakingshortageof 0.9% respectively for 2019–20 financial year. Thisimbalance between thedemand (1.271trillion units) and supply (1.275 trillion units) ratio ischallenging. This motivated us to conserve the usageofelectricalenergyandaddtotheelectricitygener ationbyinstallingdistributinggenerationsystems.
Electrical energy audit as mentioned beforeisa cumbersome process.

Followingstepsareinvolvedinamanual,genericelectri calenergyaudit[1]:
Clearly the process of electrical energy auditis an exacting one. Hence introduction of automationcould help in reducing a lot of man hours. An onlinesystemensurestheproductreachesthemaximu mnumberofpotentialusers.Italsoeliminatesthecryptic jargonsmentionedabove andenables a layman toconductanelectricalenergyauditandobtaintheappro priate recommendations to conserve electricalenergy.

- Collecttheloaddetailsforelectricalequipmentwit h highelectricityconsumption.
- Calculatetheusageloadafterdesigningthesingleli nediagrambyfeedingthevaluesinETAP[A].
- Plotrealtimeloadcurvebyusingtheenergymetera ndmeasuringKw/HR[B]for20days.
- Calculatetheconnectedloadwithrespecttosinglel ine diagram.
- Plotagraphbetweenyearsandtariff.
- Identifyandcalculatetheunnecessaryusageandp owerwastageinthelayoutwithgraph.
- Drawthepowerutilizationchartwithrespecttothel ayout.
- Calculatethedailyutilizationofpowerofalltheequ ipmentand convertthemto apie chart.
- Collectdataofallthemajorequipmentandfindoutt he performance.
- Interactionabouttheenergyusagewiththeconcern edpartyalong withsuitablesurvey.
- Identifyenergyconservationsopportunity,ifany.
- Provide a report on suitable recommendation forexistingappliancesandsuggestionsforimplem entationofenergyconservativemeasures.
- PlotCostBenefitAnalysiswithBreakevenChart
- Checktheearthresistanceandreportonthestatusof earthinginthat concern.
- ProvideAwarenessonElectricalSafety.
- SubmissionofSuitableEnergyAuditReportwith Breakeven Analysis and taking the benefits ofrenewable energy and simulating it in the ETAPsoftware and provide the best recommendation toreduceelectricalconsumptionbyrenewablesou rces.

The first step towards conserving electricityisconductinganelectricalenergyconsumpti

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onsurvey. This helps us in understanding of the patternsin the usage of electrical energy. The second step inthisprocessisconductingelectricalenergyaudit.Heretheuserwillfeedthesystemwithdatarelevanttotheirelectrical usage such as: total energy consumption inwatts, age of equipment and the time of usage per dayetc. The third step here would be analyses of data.EARES,oncefurnishedwiththerequireddatawill analyze it and generate information that will aid therecommendation system to chalk out the appropriaterecommendations.Thefinalstepherewillbeprovidingtheuserswithsuitablerecommendations.

A.LITERARY REASEARCH

Energy audit can be described as inspection,surveyandanalysisofenergyflowforenergyconservation in a building, process ora system toreduce the amount of energy input into the systemwithoutnegativelyaffectingtheoutput.Incommercialand industrial and real estate, an energy audit is the firststepinidentifyingopportunitiestoreduceenergyexpenseandcarbon footprints in the energy audit.[2].
Energyauditsinitiallybecamepopularinresponse to the energy crisis of 1970 and later years.Interest in energy audits has recently increased as aresultofgrowingunderstandingofhumanimpactupon globalwarmingandclimatechange.Energyaudits are also popular due to financial incentives forhomeowners and industries.
Auditscouldfurtherbeclassifiedasfollows

1) **Home energy audit**- A home energy auditis a service where the energy efficiency of a house isevaluated by a person using professional equipment(such as blower doors and infrared cameras), with theaimtosuggestthebestwaystoimproveenergyefficiency in heating, cooling and lighting the house.Ahomeenergyauditisoftenusedtoidentify cost effective ways to improve the comfort and efficiencyof buildings. Recently, the improvement of computer&smartphonetechnologyhasenabledhomeownerstoperform relatively sophisticated energy audits of theirown homes. This technique has been identified as amethodtoaccelerateenergyefficiencyimprovements.

2) **Industrial energy audits**- Increasingly inthe last several decades, industrial energy audits havebecomewidespread.Thedemandtolowerincreasingly expensive energy costs andmovetowardsa sustainable future have made energy audits greatlyimportant.Theirimportanceismagnifiedsinceenergyspending is a major expense to industrial companies(energy spending accounts for10% of the averagemanufacturer's expenses). This growing trend shouldonly continue as energy costs continue to rise. Whilethe overall conceptsare similar to a home or residentialenergyaudit,industrialenergyauditsrequireadifferent skillset for different energy audits.[2]

Energy audit is an evolving domain. Therearefewsystemsexistinginthisfieldandfewersystemswithautomation.Amajorityofthesetasksaredone manually. These procedures are incommodiouswhichdrasticallyreducestheeffectivenessoftheprocess.Existingsystemsareeitherineffectiveinanalyzingthedataefficientlyorincompatiblewiththeframeworkoftheconsumer.Thus,amajorityofpeoplearedeprived from obtaining the benefits from thissystem. Some existing energy audit system charge onmonetary basis for their services. These are some ofthesetbacks withtheexisting systems.
Let us have a look at some of the recentdevelopments in this domain. Some of the existingsoftwareofenergyauditareEnergyGaugeUSA,NationalEnergyAuditTool(NEAT),EnergyPerformance Score (EPS), B Eopt™ (Building EnergyOptimization).Thesetoolsareextremelysophisticated. Most of them are incompatible with theframeworkofanIndianhousehold.
Aresearch[3]suggeststhepresenceofinformation gap between the auditors and the houseowners.Notenoughhomeownersknowaboutorunderstandaudits,andthefollow-throughonrecommendationsaftercompletionofauditisimperfect. This motivated us to create an awarenessabout energy audit and implementation of distributedgenerationandrecommendationstoconserveenergy

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Another research [4] suggests methodologiestoconserveenergyinindustrialplantsb yreducingtheelectricalenergyconsumed bylightingappliances.
One of the studies[5] concludes with an auditof lighting equipment, motors and harmonic analysis,butfailstoaddressconcernslikecoolingsyste m,heavymachineriesandotherenergyconsumingfact ors. There are various techniques listedout bymultipleresearchpublications[6]toconserveelectric ityinahomeaswellasanindustrialenvironment.Butthe setechniquesmissoutonencompassing other household or industrial electricalappliancesweretherethereisapossibleleakageof electricalenergy.Thisencouragedustodesignacompre hensive system encompassing various factorsthatmightplayapivotalrolein theelectricityconsumption.
Further investigation elucidates these factorslike accuracy of existing tools, their marketplace andtheircorrespondingattributessuchasclimateetc.,e aseof usage and other similar aspects play an essentialroleinperforminganefficientenergyaudit.E ARES is designed keeping in mind all the abovelisted issues. We have tried to address all the possibleconstraintsinenergyauditingprocedureandh avedevisedanall-inclusivesystemin EARES.

II. PROPOSEDSYSTEM

The proposed system will include an onlinesurvey.Thissurveycontainsasetofgenericquest ionsthattheusersarerequiredtoanswer.Thissurveyhel psus analyze the electrical usage tendencies of the userof this system. It also furnishes us with the detailsregardingthepatternsinusageofelectricityande lectrical appliances. This information could help uscreateabetter understandingofenergyusagetrends.

Theenergyauditapplicationwilltakeanarray of information such as total rating (electricityconsumptioninwatts),ageofequipment,ti meofusageandBEE[C]starratingconcerningvariousel ectrical appliances that are present in a household.Theapplicationwillcalculatetheamountof electricityconsumed and the cost incurred by each and everyelectrical appliance. This information will act as aninputto the recommendation system.

Therecommendationsystemwillprovidethe user with generic as well as specific recommendations.Theserecommendationsmayormay notinvolveinvestments.Theserecommendationsareg eneratedbytakingintoconsiderationtheplethorainfor mationthat is acquired from the user specific audit as well as thegenericsurvey. Our application allows theuser toperform more than one audit. Users will also be ableto accessthedetailsfrompreviouslyperformedaud it(s) thus enabling them to compare the resultsfrom more than one audit. The further section willdiscussindetailabouttheproceduresinvolvedinde velopmentand implementationofthissystem.

India has emerged as a global leader in renewable energy, notably in solar power. By end of November 2019 grid-connected renewable electricity capacity had reached 84 GW, including 32.5 GW from solar PV and around 37 GW from onshore wind as well as small hydro. The GOI adopted an ambitious target of 175 GW renewable electricity capacity by 2022; the target is sub-divided into 60 GW utility-scale solar PV, 40 GW rooftop solar, 60 GW wind power, 10 GW bioenergy and 5 GW small hydro. In 2019.

A. METHODOLOGY

EnergyAuditinvolvesthe followingprocedures

1) StatisticalDataCollection

Currently the collection of data for thesystem is done by a team of students whoinspect the usage of electricity in a housemanually.Collectionofdatainvolvesthefoll owingsteps.

a) Preparation of Power DistributionSingle Line Diagram - Collect alltheloaddetailsforelectricalequipmentwithhig helectricityconsumptionandcalculatetheusagelo adaftersinglelinediagramhasbeen fedwithload values.
b) Real time lode curve - Plot real timeloadcurvebytakingtheenergymeter KWHR,for20 days.
c) Real time power loss - Identify andcalculatetheunnecessaryusageandpowerwas tage in the layoutwith graph.
d) EquipmentLifeCycleAnalysis- Datacollectionofallthemajorequipmentandfind outtheirrespectiveperformance.

2) ElectricalUsageInvestigation

Asurveywillbeconductedforobtainingthedatatomine specificpatternsintheelectricalusage.

a) Interviewwithfacultymembers-Interview with faculty members tounderstand the trends in electricalusage.
b) StudytheStatusofEarthing- Checktheearthresistanceandreportonthestatusof earthinginthatconcern.

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3) StatisticalDataCalculation

Calculation of these data is a difficulttask. We aim to bring in automation in theprocessofcalculation.

- Loadcalculationofsinglelinediagram - Calculate the connectedloadwithrespecttosinglelinediagram .
- Energy Meter Tariff Graph - Plot agraphbetween yearsand tariff.
- Power utilization chart - Draw thepower utilization chart with respectto the layout.
- **StatisticalData Analysis**

Analysis involves analyzing the data forspecificusagepatterns.The followingstepisinvolved inthestatisticaldataanalysis.

- Energy conservation opportunity- Identifytheenergyconservationopportunities.

3) **IMPLEMENTATION**

OEAREMSaidsmostoftheabovementionedprocessb yintroducingautomation.OEAREMScanbedividedin tovarioussubmodulesaslisted below.

1)OnlineSurvey

Onlinesurveyisapartofenergyaudit.Everyti meausertakesanaudit,heisrequiredtogothroughthe survey. The survey consists of generic questionsrelatedtoconsumptionofelectricityandusag epatternsofelectronicappliances.Thesequestionswer edesignedbyourpeersinthedepartmentofelectricalan delectronicengineering.Thissurveymakesusawareof thedevelopmentsinusageofelectrical energy and electronic appliances. Once aquestionisanswered,thesurveyapplicationinstantan eously displays the results of the survey ingraphicalformat.

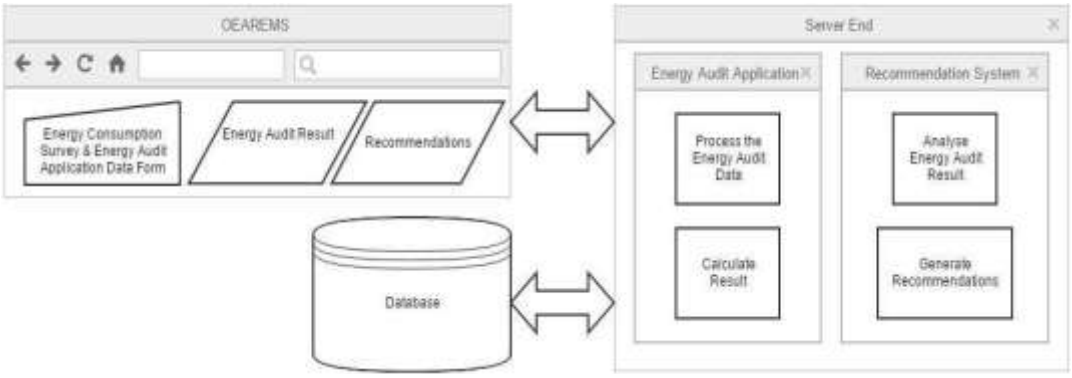

Fig1.ArchitectureofEnergyAuditandRenewableEnergySystem

5) **Recommendation**

Oncethedataisanalyzedsuitablerecommendations are provided to the users.Following steps are involved in the processofrecommendation.

a) Recommendation – Provide a reportonsuitablerecommendationforexisting appliances and suggestionsforimplementationofenergyconserv ativemeasures.
b) Costbenefits- Plotcostbenefitanalysiswithbreakevenchart.
c) AwarenessonElectricalSafety- Provideawarenessonelectricalsafetyto theconcerned users.

2) EnergyAuditApplication

EnergyAuditApplicationisasophisticated,y etauserfriendlyapplication.Thisapplicationconsistso fadynamicdatacollectionsheet,where the user is required to feed data associated toelectrical equipment. This data might be number ofequipment,totalrating(electricityconsumptioninw atts), age of equipment, time of usage and BEE starrating,dependinguponheattributesoftheequipme nt.Once the data is fed into the system, the energy auditapplicationcalculatestheamountofenergyconsu medbyeachequipmentandthecostincurredbythem.Th eformulae used in calculation of energy consumed andcostincurredare listedahead.

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$$(W)^T = (R)^T \times (T)^T$$

$(W)^T$ = Total Number of Watts Consumed Per Day.
$(R)^T$ = Total Rating.
$(T)^T$ = Time of Usage.

(1)

$$(W)^{TY} = (W)^T \times 365$$

$(W)^{TY}$ = Total Number of Watts Consumed Per Year
$(W)^T$ = Total Number of Watts Consumed Per Day.

(2)

$$(U)^{TY} = \frac{(W)^{TY}}{1000}$$

$(U)^{TY}$ = Total Number of Units Consumed Per Year
$(W)^{TY}$ = Total Number of Watts Consumed Per Year

(3)

$$(C)^{TY} = (U)^C \times (U)^{TY}$$

$(C)^{TY}$ = Total Cost Incurred Per Year
$(U)^C$ = Cost Per Unit
$(U)^{TY}$ = Total Number of Units Consumed Per Year

(4)

Equation (1) is used to calculate the totalnumberofWattsconsumedperday,Equation(2)involvescalculationoftotalWattsconsumedperyear,while Equation (3) determines the units of electricityconsumedperyeartheEquation(4)isusedtoestimatethecostincurredbytheuseroveraperiodofoneyear.

3) Recommendation System

Recommendationsystemdolesoutrecommendation to conserve electrical energy. Theserecommendations would be generic as well as userspecific.Recommendationsystemutilizesthedata obtained from the energy audit application to chalk outtheuserspecificrecommendation.

Underfollowingcircumstances,therecommendations ystemwillsuggestreplacement.

CompactFluorescentLamp=TimeofUsage>7hours& TotalRating> 18W

Recommendation-
ReplacementofCFLwithenergyefficient**LED** lamp.

TubeLight=TimeofUsage>2hours&TotalRating > 40W

Recommendation-
ReplacementofTubeLightwithenergyefficient**LED**l amp.

AirConditioner=TimeofUsage>5hours&BeeStarRat ing<3 star & AgeofEquipment>3years

Recommendation-
ReplacementofACwithenergyefficient**BEE**StarRate dAC.

Fan=TimeofUsage>5hours&TotalRating>60W

Recommendation-
Replacementoffanwithenergyefficient**BEE**StarRate d fan.

Refrigerator=BeeStarRating<3stars&AgeofEquipm ent> 3years

Recommendation-
Replacementofrefrigeratorwithenergyefficient **BEE**StarRatedrefrigerator.

Equipments	No	Recommendation	Before Replace	After Replace	Watt's Saved	Money's Saved
Ceiling Fan	2	Replace the fan with star rated fan	219	91.25	127.75	383.25
TubeLight	1	Replace the Light With LED Light	109.5	43.8	65.7	197.1

Fig2.ASampleRecommendation GeneratedforaDiningHall

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Implementationoftheserecommendationscouldleadtoenergyconservation.Therecommendation system also provides you with theenergyconsumptiondetailsandmonitorysavingsdetail, before andafter replacement.

III. RESULTS

The table below illustrates the cost benefitincurred from replacing a 55W Florescent Tube lightwith15WLED.LEDshaveagenerallifeexpectancy

Equipment	TotalRating in watts	Hoursperday	Wattsconsumed Annually	Unitsconsumed Annually	CostAnnually RS	UnitsSaved Annually	MoneySaved Annually RS
Florescent TubeLight	55	5	100375	100.375	301.125	73	219
LED	15	5	27375	27.375	82.125		
PaybackPeriod							
(Investmentcost(CostofLED)/Annualsaving)*12 months=(700/219)*12=38.3Months							

Table1.ResultofImplementationofRecommendations.

of50000hrs.Ifyouuseyourlightsfor10hoursaday,this should be 13.7 years, taking this into accountevery time you use a LED light after its payback periodit adds up as profit earned. Implementation of Energyauditnotonlyhelpsinconservationofenergybutalsohaseconomic benefitsattachedtoit.

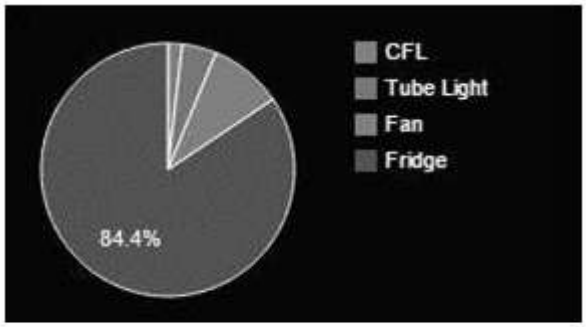

Fig 3. A Sample Survey Result Depicting the Energy consumptioninakitchen

The result above illustrates the changing aFlorescent Tube Light with LED could help you savearound 73 units annually, roughly translating it into asavingof 219consideringaunitofelectricitycosts 3. This implies that within a period of 3 years wewould get our investment back. Any amount savedafterthatperiodcouldbeconsideredasprofit.Allt hisjustbyreplacingoneFlorescentTubeLight.Replaci ng multiple electrical appliances with star rating could furtheraidtheenergyconservationprocessandresultsi n theenvironmentalaswellasfinancialbenefits overaperiodoftime have some benefits.

IV. CONCLUSION

Energy audit and renewable energysystemprovidesthepublicwithaplatform to conduct electrical energy audit and obtainmeasurestoconserveenergywithminimaleffort .Thissystem provides abstraction to the user from internalcomplexities of energy audit process thus making itmore accessible to the wider sections of our society.As it was said, ‘prevention is better than cure’, thesameway ‘conservation is better than generation’.Withthestaggeringincreaseinthedemand forelectrical energy EARES provides a pathway toconserve theelectricityandtotheimplementationprocessfor distributed generation.

Monitory benefits itself it can act as a greatmotivatorthe encouragingpeopletoadoptenergyconservativemeth ods to save the

electricity.Apartfromthatenergyconservation also eases the disparity prevalent in theavailabilityofelectricalenergy.Italsolessensthetoll it takesittakesonournatureandnaturalresourcestogenerateelectricity, hence helping the environment.Hence itisvitalthatweconserveenergyandactasaresponsible predecessorfor thefuturegenerations.

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SYNONYMS

[A] ETAP-ETAPelectricalengineeringsoftwareisapowersystemsanalysissolutionthatincludesanalytical software modules for load flow, arc flash,loadflow,shortcircuit,transientstability,relaycoordination,cableampacity,optimalpowerflowetc.
[B] Kw/HR - The kilowatt per hour is a derived unit ofenergyequalto3.6megajoules.Iftheenergyisbeingtransmitted or used at a constant rate(power) over aperiodoftime, thetotalenergyinkilowatt-hoursistheproduct of the power in kilowatts and the time inhours.
[C] BEE-BureauofEnergyEfficiency.