A Literature Review for Cloud Based Efficient Energy Audit Management System using Machine Learning

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Abstract: *In recent years, the combination of cloud computing and machine learning paradigm has profoundly influenced numerous industries, especially energy auditing - a crucial factor deciding economy of power system.Energy auditing is necessary for optimizing energy utilization, lowering costs, and generally enhancing the efficiency of operation. Conventional techniques of auditing are effective but cannot handle huge datasets, hindering the speed of processing, and arising the requirement for real-time decision-making, thereby making ML and cloud computing a useful assets.This literature survey discusses various energy auditing methods, with a focus on how machine learning algorithms such as supervised learning, unsupervised learning, hybrid models, kernel methods, Bayesian inference, and persistence models play an important role in enhancing the accuracy of audits. In addition, the use of cloud computing allows for remote access to real-time audit information, making it possible for industries to maximize their energy management. This integration not only simplifies the auditing processes but also reduces human error, thus promoting a data-driven automated energy conservation process. This survey identified the best techniques to perform the audit with ML and cloud computing..*

Keywords:*Supervisedlearning,unsupervisedlearning,hybridtechniques,kernelmethod, bayesian inference, persistence model, cloud computing.*

1. INTRODUCTION

In the era of artificial intelligence, it is important to adopt towards advanced technologies in energy auditing. It has become a paramount for achieving sustained and operational efficient process. Energy auditing is traditionally a labor-intensive and time consuming process now this can be revolutionized by the integration of cloud computing and machine learning. These techniques make a significant changes in entire process through a easily accessibledata collection either through spreadsheets of data or by using real time energy consumption monitoring . These innovations make easy data acquisition, advanced analysis, automated decision making, fostering a proactive approach to energy auditing.

A cloud-based energy auditmanagement system leverages the scalability and accessibility of cloud platforms to centralize energy data from diverse formslike

sheets and devices. This centralized architectureallowsseamlessprocess,analysis, reporting of energy usage across facilities.

The incorporation of machine learning further enhances the overall efficiency in predicting anomaly detection, forecasting, optimized and faster solutions than that of traditional way,this uncover usage patterns, consumption trends, renewable energy analysis and predict future demands with higher accuracy. These insights empower organizations to identify inefficiencies, reduce energywastage, and adopt renewable energy sources strategically which streamlines energy audit process and also aligns global sustainability goals.This literature review explores the architecture, machine learning techniques, and practical applications of cloud-based energy audit management systems, emphasizing their potential to revolutionize energy management practices globally. This paper focuses on the research question : What are

different techniques of machine learning used for efficient energy auditing and cloud computingadheresforit?Thisalsogivesasumma ry of different machine learning techniques used for energy auditing.

2. BACKGROUNDAND METHOD

While current energy audit methodologies have some advantages,as the overall effectiveness of these methodologies is limited. Often, these approaches require a professional energy auditor, as they commonly rely on manual data collectionand analysis. This means that report generation and decision making processes is often too long. However, these methods are expensive due to need of professionalsenergy auditor , specialized instrumentation, and large labor, which makes them

uneconomical for small and medium sized enterprises. In addition, human error in data entry can lead to inconsistencies, which may impair the reliability of the audit outcomes. Traditional techniques also do not usually provide the capability for real time monitoring of data and thus energy management is donein a reactive, rather than proactive, manner.

Data segregation is another challenge because data is scattered in multiple areas, preventing data integration and making it difficult to do a proper analysis. These methods are further constrained by the absence of sophisticated technologies like machine learning, which limits them in their capacityto do predictive analytic, anomalies, and uncover patterns and trends.Furthermore, such tools often employ standardized frameworks that cannot accommodate the diversity different important factor. Often contextual factorslike climatic variability, occupancy behavior, and emerging technological developmentsare ignored, further decreasing audit accuracy. A key to develop this responsive and scalable energy management systemsis to include major factor affecting energy consumptionlikeweather.therefore,thereisa need for introduction of new andinnovative solutions based on the latest scientific knowledge and driven by artificial intelligence.Theadvantageofdevelopingsuch innovative tools is toaccesslarge amounts of data for energy auditing(energy forecasting, analyzing energy consumption trends, evaluatingrenewable energy potential and proposing some basic energy saving plans) and experience in implementing solutions, including the use of artificial intelligence.

The proposed system concerns data from excel sheet as .xlsx file, solution based on artificial intelligence, machine learning andbig data and provides full-scale analysis of given data.this paper was created based on the analysis of the similar literature reviews using the advantages and improving the different ideologies from those.

Similar review on using machine learning in energy auditing and cloud computing inenergy management are available. In the[1] survey evaluates various modeling techniques for predicting electricity energy consumption which provides actionable insights for utility companies in optimizing predictive models to enhance energy demand estimation and planning. The major remark would be not including of meteorological variables such as temperature and wind velocity should improve the model fitting results . The [21] focuses on improving energy consumption prediction models using machine learning and sampling strategies.

This work include further investigation on gradient-based sampling strategies. The machine learning model can also be extended to deep learning field to handle high-dimensionalinputscenario.Thepaper
[3] discusses the integration of cloud computing in smart grids to enhance energy management and distribution. It provides a detailed analysis of current research, methods, and models, highlighting the benefits and innovations cloud computing brings to smart grid architecture. The studiesarrangement is economical for the utilities since theyneed not invest on communication and computing facilities.In[16]aninnovativestrategyfor optimizing the upload of large data to distributed cloud systems, employing a unique

combination of multipart data slicing and combinational optimization is used. By formalizing the process into an optimization problemandleveragingstochasticmethodslike simulated annealing, the strategy offers a significant reduction in both transfer costs and time, outperforming traditional single-vendor cloudsolutions.Optimaluploadingschemestill is not covering internal transfer latency as well as data re-transferring during the lost.

3. RESULT

This section contains an overview of reviewed machinelearningmethods.Thepublications werecategorizedby machine learning method type: Supervised machine learning (SML) and Unsupervised machine learning(UML),Time Series Analysis,Hybrid Models,Probabilistic Models,Specialized Techniques and bythe task of the classifier.

A. SupervisedMachineLearning

A SML algorithm uses labeled data samples that include data entries with and without malicious activity to learn and afterward makea prediction. These types of algorithms aregood for learningattack patterns and predicting a possible incident.

A variety of SML algorithms performing both classification and regression tasks are considered in the literature (Table I) including algorithms like Regression Techniques**:**Regression (General),Linear Regression (LR),Multiple Linear Regression (MLR),Support Vector Regression (SVR),Polynomial Kernel in SVR,Ridge Regression,Lasso Regression. Tree-based models : decision trees, random forests, and classification and regression trees . Neural networks : feed-forward neural networks and artificial neural networks. Support Vector Machines (SVMs): LS-SVMs(Least Squares SupportVectorMachines),andSVRwith radial basis function kernels. Instance-based learning methods : k-nearest neighbors.

B. Unsupervisedmachinelearning

An UML algorithm discovers hidden data patterns by using an unlabeled data set in the learning process. In contrast to SML algorithms,Unsupervised learning algorithms are designed to identify patterns or clusters in data without labels,which helps in anomaly detection. Clustering techniques include k-means and agglomerative hierarchical clustering. Dimensionality reduction techniques, such as principal component analysis also fall into this category.

C. TimeSeries Analysis

Time series analysis algorithms are used for forecasting and working with sequential data. Examples include Auto-Regressive Integrated Moving Average (ARIMA)

D. Hybrid Models

Hybrid models combine approaches for specialized tasks. Examples include ensemble methods like LSBoost and resampling, fuzzy systems such as adaptive near-fuzzy systems and fuzzy modeling.

E. Probabilistic Models

Probabilistic models are based on probabilistic reasoning, with Bayesian Networks being a prime example.

F. Multi-Modal Regression

Multi-modal regression methods include Gaussian process regression and neuro-adaptive methods, while evolutionary models include LMSR (Least Mean Square Regression).

Cloud computing in [3]enhances smart grid capabilities by improving scalability, cost-efficiency, and real-time data processing.A promising future lies in further integrating cloud technologies for optimized power management, monitoring, and economic dispatching. The survey [4] has achieved 93%

accuracy for training data and 92% for test data and also identified significant factors influencing EUI automatically.This study presents a decision tree based method to accurately predict and classify residential building energy demand, offering insights for architects and energy conservation. In this [6] RBF kernel maintained strong predictive performance even after feature selection, with theMeanSquaredError(MSE)rangingfrom 4.4e-4 to 4.8e-4 before feature selection and varying from 3.7e-4 to 2.1e-3 after, while the

Squared Correlation Coefficient (SCC) remained high at 0.97 before and between 0.96 and0.97after.For trainingthesampleof survey [7], ANN achieved an accuracy of 65% withaMeanSquaredError(MSE)of0.09, whileSVMachieved64%accuracywithan MSE of 0.10; for the test sample, ANN had 62% accuracyandanMSEof 0.10,andSVMhad60% accuracy with an MSE of 0.11.The proposed [9] EnergyCloudsystemoffersinnovativetoolsfor real-time monitoring and analysis, providingindustrieswithactionableinsightsandimprovedefficiency.Thesedevelopments pavethewayforsustainableandintelligent energymanagementpractices,addressingthe complexitiesandscaleofmodernindustrial operations.

In [12], ANN with PCA and detailed feature data (M3) yields high-accuracy predictions.Machine learning can enable smarter energy use in higher education, especially when fine-grained data is considered.Highlights scope for extending this to broader educational or institutional applications.Here [13] the integration of fog computing into the IoE framework allows scalable, real-time demand-side energy management,especiallysuitedformicrogrids

Study	Purpose	Algorithms	Bestperformance
[1]	Energyconsumption in Hongkong	REGRESSION, DT, NN	DT,NN
[2]	Best fitmodelforfamilyhome	SVR,LR,KNN,RF,DT	LR,SVR-(combines togive85.7%accuracy)
[4]	Japaneseresidentialbuildingpredictand classifying euilevel	DT,ANN,REGRESSION	DT
[5]	Home's future electricityconsumption	FFNN,SVR,LR, LS-SVM	LS-SVM
[6]	Office building energyconsumption	SVR-RBF,POLYNOMIALKERNEL	RBFis stable
[7]	Individualhouseholdlevel	NN,SVM,	Bothgivesgoodprediction with leasterrorandacceptableaccuracy
[8]	Forecastingmodelforpoland	CART,ARIMA, RF, ANN	RFis effective
[11]	Short term forecasting usingconsumer dailyloadprofile	MLR,ARIMA,LR, K-MEANS,AHC,FMM,SOM	Clusteringmodels are better thanregression
[12]	Forecasting in universitycampus	ANN,SVR,PCA,FM	Performance:ANN>SVR,accuracy:PCA>FA
[14]	Prediction in residential and commercialentities	ANN,SVM,RF	Allthethreegot90%accuracy
[17]	Citywiseenergydemandprediction	NARM,LMSR, RF, LSBoost	Coefficient of variation:LSboost-5.019%(summer), 3.0159(autumn),3.292%(winter),3.14%(spring)
[19]	Africaindustrialenergyconsumption	SVM	SVMhas0.9correlationcoefficient
[21]	Predict the enrgyconsumption ofsmartbuidings	SVM,ANN,RF	RF
[22]	Energyauditforhouseholdlevel	LR,DT,RF	RF-91% performancesuperior
[23]	Prediction of weather based smarthomeEnergy consumption	SVR,LR,RF,DT,KNN,ANN, Fuzzy, Lasso	SVR-30.96(MSE)

with high penetration of renewable resources. The proposed system enhances operational efficiency, consumer flexibility, and grid responsiveness.In [14] the random forest classifier achieved the highest classification accuracy at 92.28%, followed closely by the support vector classifier at 91.38%, and the artificial neural network at 89.89%.For five energy levels, the random forest again performed best with 83.40% accuracy, the

Table:2 A fine summary of individual paper

S.NO	JOURNAL NAME	AUTHOR NAME	DESCRIPTION	OUTPUT
1.	Predicting electricity energy consumption: A comparison of regression analysis, decision tree and neural networks	Tso, G. K. and K. K. Yau	Compares regression, decision tree, and neural networks consumption prediction	determines the most accurate approach for electricity consumption prediction.
2.	Machine Learning Models for Electricity Consumption Forecasting	Gonzalez-Briones, A., Hernandez, G., Corchado, J. M.Omatu, S., & Mohamad	electricity consumption forecasting, presented at ICCAIS 2019.	forecasting electricity consumption, improving efficiency in energy management systems.
3.	Cloud computing for energy management in smart grid - an application survey	P Naveen , Wong Kiing Ing, Michael Kobina Danquah , Amandeep S Sidhu, and Ahmed Abu-Siada	in-depth survey on different cloud computing applications for energy management in the smart grid architecture	more memory and storage to evaluate computing mechanism for energy management cost-effective cloud based power dispatching
4.	A decision tree method for building energy demand modeling. Energy and Buildings	Yu, Z., F. Haghighat, B. C. Fung, and H. Yoshino	Develops a decision tree method for building energy demand modeling	Improvedemand forecasting for building energy consumption.
5.	Predicting future hourly Residentialelectricalconsu-mption: A machine learning case study. Energy and Buildings	Edwards, R.E., New, J., Parker, L.E	hourly electricity consumption prediction	provides insights into energy-savingopportunities.
6.	FeatureSelection for Predicting Building Energy Consumption Based on Statistical Learning Method	H. Zhao and F. Magoul`es	Proposes feature selection techniques for predicting building energy consumption, published in Journal of Algorithms & Computational Technology.	Feature selection methods significantly impact the accuracy of building energy prediction models.

7.	Short term electricity forecastingusingin dividual smart meter data,	K. Gajowniczek and T. Zbkowski	Examines short-term electricity forecasting using individual smart meter data, published in Procedia Computer Science	Short-termforecasting of electricity optimize consumption of energy and grid stability.
8.	"Short-TermLoad Forecaste Using RandomForests".In Intelligent Systems	G. Dudek	Uses random forests for short-term load forecasting	offer reliable solutions for short-term load forecasting in energy systems.
9.	Energy Cloud: real-time cloud-nativeEnergy Management System to monitor and analyze energy consumption in multiple industrial sites	Hugo Sequeira and Paulo Carreira Thomas Goldschmidt and Philipp Vorst	cross-site monitoring of energy consumption	architectural solution to address the industrial needs with current EMS implementations raise new opportunities for energy and cost savings.
10.	Cloud computing and continuous energy consumption management	Dr.Viorel Lupu	Continuous measurement networks Digital energy management	To increase energy and cost savings Accurate data flow
11.	Enhancing household level load forecasts using daily load profile clustering	E. Barbour and M. González	Explores household-level load forecasting using daily load profile clustering	Load profile clustering effectivelyimproves the household-level energy forecasting. enabling better energy distribution and planning.
12.	Forecasting powerConsu-mption for hr.educationalinstitutions based on machine learning	Jihoon Moon, Jinwoong Park, Eenjun Hwang	Investigates power consumption forecasting in educational institutions using machine learning, published in The Journal of Supercomputing.	Optimize the power consumption in higher educational institutions reducing operational costs.

13.	Demand Side Management Using the Internet of Energy based on Fog and Cloud Computing	Kolsoom Shahryari, Amjad Anvari-Moghaddam	provides bidirectional flow of information and power is internet of energy (IoE)	handle this multiplicity huge amount of data generated by IoT
14.	Energy Consumption Level Prediction Based on Classification Approach with Machine Learning Technique.	Chang, H.-C.; Kuo, C.-C.; Chen, Y.-T.;Wu,W.-B.; Piedad, E.J.	Uses classification-based machine learning for predicting energy consumption	enhance energy consumption prediction and management.
15.	Energy Management of Smart Grid using Cloud Computing	Mr. Manoj Hans,Pallavi Phad,Dr. Vivekkant Jogi,Dr. P. Udayakumar	feasible by monitoring real-time readings create project supported cloud computing	distributing and browsing an entire energy management program real-time information
16.	A Novel Approach for Optimal Data Uploading to the Distributed Cloud Storage Systems	Agil Yolchuyev	handle and to access big data objects an optimal uploading strategy	distributed storage uploading strategy to cloud storages
17.	Nonlinear autoregressive and random forest approaches to 198 forecasting electricity load for utility energy management systems	Ahmad, T. and H. Chen	Studies nonlinear autoregressive and random forest methods for forecasting electricity load	robust solutions for electricity load forecasting.

18.	Cloud Computing Based Smart Energy Monitoring System	R.Govindarajan, Dr.S.Meikandasivam, Dr.D.Vijayakumar	to develop the Smart Energy Monitoring System (SEMS) using Cloud Computing. to monitor the data as well as store the data in cloud server real time as a live energy report	to implement the closed loop power communication reduce standby power consumption
19.	Predicting Industrial Sector's Energy Consumption: Application of Support Vector Machine	Oludolapo A. Olanrewaju	To reduce its consumptionplanning accessibility to energy demand	to forecast yearly energy consumptionprevent incessant increase in emission rate.
20.	An integrated platform for smart energy management: The CCSEM project	Emmanuel Luján, Alejandro Otero, Sebastián Valenzuela, Esteban Mocskos , Luiz Angelo Steffenel , Sergio Nesmachnow	low-cost IoT deviceFor smart energy monitoring a suitable cellular technology for Smart Grid outage restoration and management message analysis of domestic consumption patterns	forecast the generation of individual PV systems energy consumption and smart planning
21.	Sampling Strategy Analysis of Machine Learning Models for Energy Consumption Prediction	Zeqing Wu,Weishen Chu	construction of smart citysampling density over the data	to predict the energy consumption improve the prediction accuracy computational efficiency
22.	Energy Audit System for Households using ML	A.Nagesh	use of ml to improve energy efficiency and conservation . different models can predict energy consumption patterns provide insights for optimizing energy usage. the study aims to enhance sustainability Reduce unnecessary power consumption	Predicts the consumption of energy identifies areas of wastage enabling better energy efficiency and conservation optimized energy usage.

23.	An Innovative Machine Learning Technique for the Prediction of Weather Based Smart Home Energy Consumption	Shamaila Iram , HussainAlaqrabi Hafiz Muhammad Shakeel, Hafiz Muhammadathar Farid, Muhammad Riaz , RichardHill,Prabanchan Vethathir , And Tariq Alsboui	reducing the cost of power generation improve energy sustainability economic stability	to predict energy consumption of smart home appliances
24.	Comparative analysis of machine learning algorithms for the building energy prediction	Ritwik Mohan.,Shashank Devneni,Sai Sumpreet,Vijay Mohan,Nikhil Pachauri	to reduce energy consumption to improve HVAC functionality to estimate the hyperparameters	to predict energy consumed by the heating load. rigorous analysis
25.	A Review Study on Energy Consumption in Cloud Computing	Oğuzhan Şereflişan , Havelsan,Murat Koyuncu	comparing various methodologies aimed at achieving energy efficiency without sacrificing performance practical implementation of energy-efficient solutions in cloud environments.	To enhances application portability, accelerates the cycles of application development and deployment, and leads to better resource utilization and scalability.
26.	Design of a Home Energy Management System Based on Cloud Service	YongMei Jiang,Yang Yang,QiuXuan Wu,XiaoNi Chi	application of new energy in the home micro-gridmonitoring of energy in the home	facilitate the life of users, improve the ability of users to monitor enhance the habit of using electricity
27.	A Literature Review of Machine Learning Techniques for Cybersecurity in Data Centers	Evita Roponena, Janis Kampars, Andris Gailitis ,Janis Strods	different machine learning techniques and feature sets used in cybersecurity for an ICT system security analysis.	review existing machine learning methods and technologies used for maintaining high ICT cyber security level

support vector classifier reached 81.07%, and the artificial neural network had 78.07%.With seven energy levels, classification accuracy dropped across all models, with random forest at76.39%,supportvectorclassifierat72.57%, and artificial neural network at 66.51%.

This work [15] explores the integration ofcloud computing within smart grids to enhance energy management, providing solutions for peak load reduction and offering increased reliability with the support of real-time data monitoring systems. The [18] proposes cloud-based solution provides scalable and reliable serviceformillions ofusers,contributingto the smartenergymanagementinsmartgrids.The [20] project isa research effort to develop an integrated platform that allows for the intelligent monitoring, control, and planning of energyconsumptionandgenerationinurban contexts. Thisproject contributes to the design of devices and strategies to optimize the use of energy resources, with a focus on sustainability andcitizenparticipation.Improvementsin communicationinfrastructureandforecasting modelsarealsoproposedtomoreeffectively manage renewable andnon-renewable sources in the field of smart powergrids. [24] ConcludesthatmodeloptimizationusingRS can effectively predict heating loads, aiding in energyefficiencyimprovements. Thepaper[25] provides an extensive review of energy consumption issues in cloud computing, focusingonalgorithmsforVirtualMachines and container management. It highlights innovativemethodologiesfrom2018-2023for energy efficiency without compromising performance,recognizingthenecessityfor sustainable and scalable solutionsinthe evolving cloud computing landscape.

4. CONCLUSIONS

The main goal of this paper is to reviewexisting machine learning methods and cloud computing technologies used for energy auditing. This literature review has identified the current machine learning approaches and their percentage accuracy and error of different techniques.Thefindingsofthereviewwillbe usedtodesignareal-timeenergyaudit management system based on artificial intelligence and automated methods. The reviewsuggestssuitablemethodsforthefurther developmentof the project and limitations of the traditional methods. Machinelearningalgorithmsarepopularfor inbuiltlibraries whichlearnthepatterns easily, anomaly detection, prediction and forecasting. Variousresearchpapersusehybridanalyst methods combining supervised machine learning and unsupervised machine learning to avoid major disadvantage.Not all reviewed papersprovidedthesameevaluationmetrics, therefore,itisimpossibletoevaluateand compare the results of each similar study. The highermetricsystemwasimplementedto performclassificationtasksinsomeofthe research papers. The [21] voting system allow thecombiningofvarioustypesofclassifiers andafterwardanotherclassifierperformsthe aggregation of votes to make a final classification.Inmostofthesepaperslarge dataarenotusedforpredictionandforecasting purpose,only smaller datasets with least featuresareused.However,theusageofa highnumberoffeatures doesnot guaranteethe best performance of the model. Therefore, the proper selection of the feature set is important. The feature selection can be done dynamically using machine learning classifiers to adjust the model and to achieve the best accuracy. Most of the researchpapersusePython programming language to implement machine learningmodels.Pythonprogramming languageoffersdifferentlibrariesforvarious taskssuchasdatapre-processing, classification,andvisualizationthatisessential for machine learning tasks in energy auditing.Thisprogramminglanguagecanbe easily integrated with various systems. Hereby surveying the literature we foundSVM, RF, ANN,[7],[14],[22],[23]are better models for energy auditing then many others.

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