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Roles of the Web in Commercial Energy Efficiency: IoT, Cloud Computing, and Opinion Mining

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The overconsumption of energy in recent times has motivated many studies. Some of these explore the application of web technologies and machine learning models, aiming to increase energy efficiency and reduce the carbon footprint. This paper aims to review three areas that overlap between the web and energy usage in the commercial sector: IoT (Internet of Things), cloud computing and opinion mining. The paper elaborates on problems in terms of their causes, influences, and potential solutions, as found in multiple studies across these areas; and intends to identify potential gaps with the scope for further research. In the rapidly digitizing and automated world, these three areas can offer much contribution towards reducing energy consumption and making the commercial sector more energy efficient. IoT and smart manufacturing can assist much in effective production, and more efficient technologies as per energy usage. Cloud computing, with reference to its impact on green IT (information technology), is a major area that contributes towards the mitigation of carbon footprint and the reduction of costs on energy consumption. Opinion mining is significant as per the part it plays in understanding the feelings, requirements and demands of the consumers of energy as well as the related stakeholders, so as to help create more suitable policies and hence navigate towards more energy efficient strategies. This paper offers comprehensive analyses on the literature in the concerned areas to fathom the current status and explore future possibilities of research across these areas and the related multidisciplinary avenues.

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1. INTRODUCTION

Energy efficiency has become a major topic of concern with the increasing effects of anthropogenic climate change, and the need for a more sustainable society. With the commercial sector accounting for more than a third of the total U.S. energy consumption, it is crucial to improve energy efficiency in this area [EPA, 2022; IEA, 2022]. Commercial energy efficiency refers to the implementation of effectual technologies, processes, and practices mainly in industrial buildings and facilities. Commercial energy efficiency aims not only to reduce the energy consumption and lower the operating costs, but also to decrease carbon emissions, while maintaining or improving productivity and enhancing overall sustainability [Bates and Moore, 1992]. Web technologies along with machine learning can play significant roles in this sector by leveraging the processing power of cloud computing and the advanced analytics capabilities of algorithms. Organizations can gain insights into their energy usage patterns and make data-driven decisions to reduce their energy consumption [Lee et al., 2013; Chou and Ngo, 2019]. Hence, as IoT and cloud computing have become an integral part of the modern infrastructure, it is important to understand how this can help to influence the power consumption in commercial sectors and the intersection between them.

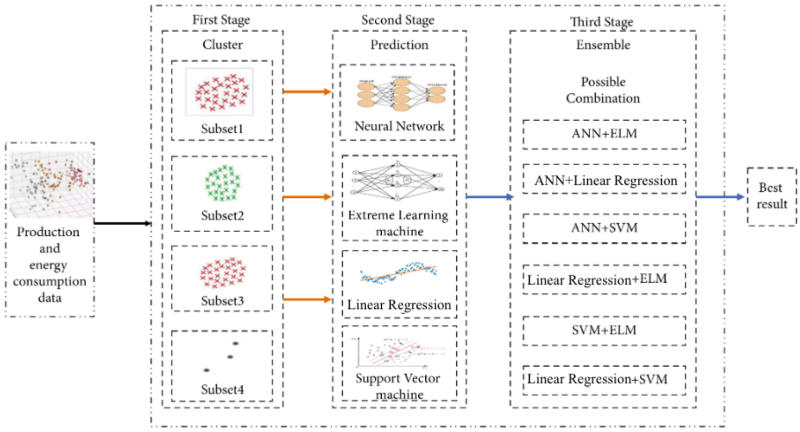

Fig. 1: Machine learning in predictive modeling for energy production & consumption [Li et al, 2021]

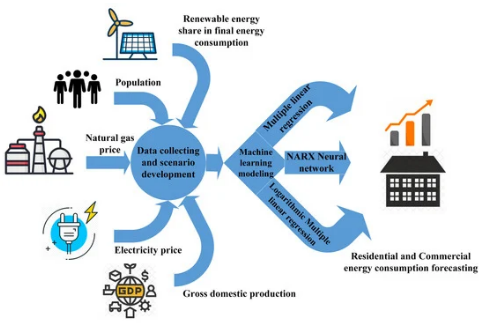

Fig. 2: Forecasting residential and commercial energy consumption [Nabavi et al., 2020]

In this matter, Fig. 1 depicts how various machine learning techniques can be used to create predictive models to help comprehend the production and consumption of energy [Li et al, 2021]. Fig. 2 illustrates how similar techniques can be used to forecast energy consumption in residential and commercial areas [Nabavi et al., 2020]. Predictive models for forecasting can help understand the use of energy, and hence reduce the energy usage and make these areas more energy efficient.

Hence, our aim in this paper is to provide an insight on various methods spanning web technology and machine learning that can be adapted for achieving energy efficiency in the commercial sector, along with an emphasis on their importance for the environment and sustainability. It entails analyzing the use and impact of green IT with cloud computing; smart manufacturing, IoT and the Industry 4.0 standard; as well as opinion mining for potential assistance in future decision-making based on current perceptions.

2. INDUSTRY 4.0, SMART MANUFACTURING & INTERNET OF THINGS

Smart manufacturing and IoT technologies can be quite crucial in improving energy efficiency in the commercial sector. Smart manufacturing leverages the usage of AI-based techniques along with more autonomy within production. In line with this, the use of data from connected devices and machines can enable manufacturers to gain more insight into their energy consumption patterns and hence optimize their energy usage. Industry 4.0 is a German initiative that started in 2011, and is also known as the fourth industrial revolution; it entails the digital transformation of the technologies by increasing automation, through smart manufacturing, and smart factories [Chang el al, 2016]. A core idea here is to create intelligent manufacturing systems that are self-sufficient and automated, harnessing digital connectivity [Afzal et al, 2019].

The manufacturing industry accounts for about three quarters of the total energy consumed by the industrial sector [IEA, 2022]. Hence, it is important to clearly understand the implications of energy consumption by this sector. There is a need to know how the new wave of industrial revolution with technologies such as smart manufacturing can help reduce energy consumption and make various processes more efficient. Smart manufacturing makes use of cutting-edge technologies to make real-time decisions to support effective, efficient, and accurate engineering through automation, data analytics, and artificial intelligence [Kang et al., 2016]. In the modern day and age, where things are more automated and data-driven, smart manufacturing techniques can help increase the efficiency of many traditional manufacturing processes [Bermeo-Ayerbe, 2022]. Traditional manufacturing processes are not interconnected; they lack automation and real-time monitoring [Shi et al, 2020]. Hence, with smart manufacturing, the erstwhile independent processes such as product development, core manufacturing, and distribution can now be well-integrated and considerably improved through advanced processes such as flexible and agile manufacturing [Agostini and Filippini, 2019]. This is proven to make the processes more efficient because machines and products interact with each other based on the set of programs, with minimal human control [Shi et al, 2020]. Likewise, with its focus on making the industry more productive, agile and efficient, the concept of smart manufacturing promotes sustainability by reducing energy consumption and carbon footprint.

An IoT-enabled software application has been proposed by researchers [Tan et al., 2017] to monitor the real-time energy efficiency in manufacturing shop floors. They introduce an approach that collates data on energy usage and production for the assessment of energy efficiency, while eliminating energy wastage during the actual process of manufacture. They apply the DEA technique (Data Envelopment Analysis) which assists them to detect various abnormalities in the patterns of energy consumption, and accordingly find gaps in energy efficiency. Fig. 3 here portrays the structure of this software as per its monitoring of energy usage. As this software tracks the real-time use of energy, it can help stakeholders enhance energy management techniques to reduce energy wastage in manufacturing.

In another study [Nimbalkar et al. 2017], a multitude of smart manufacturing technologies are examined with the goal of comprehending the manner in which these technologies can potentially be used to improve energy efficiency. In this study, researchers focus on how energy costs can possibly be reduced in process-supporting energy systems. These technologies are explored specifically in areas where motors, drives, fans, pumps, air compressors, steam, and process-heating are being used. The authors discuss three levels of smart technology applications to help increase efficiency through technologies such as automation devices, Internet-connected sensors, monitoring and control platforms. They explore various real-world scenarios where such smart manufacturing techniques are applied. They analyze how data analytics techniques in conjunction with smart manufacturing can be advantageous to help mitigate energy consumption in the commercial sector. They infer the level of smart technologies that can have higher energy savings in this matter. Likewise, other studies are conducted as well.

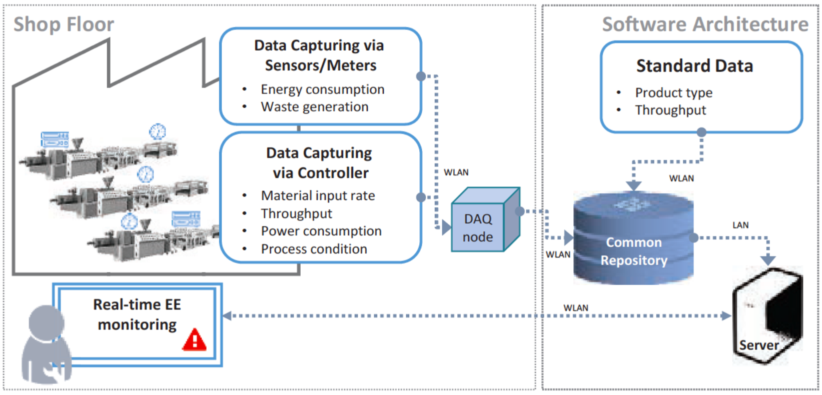

Fig. 3: Concept overview of an IoT enabled software application [Tan et al., 2017]

3. CLOUD TECHNOLOGY AND ALTERNATIVE ENERGY SOURCES

Cloud computing is an exponentially growing area, and is among the most innovative creations of the modern IT infrastructure. It has revolutionized this sector by eliminating the space, hardware, and cost for maintenance; furthermore, it has helped with increased security and integration of data. Energy efficiency is an important consideration in cloud computing because it can have significant environmental and economic impacts. Cloud computing is a rapidly growing industry, and the increasing demand for cloud services is driving up energy consumption. During the recent Covid-19 global pandemic, when all the other sectors were negatively affected, cloud technology helped people work from home and collaborate remotely, becoming an almost indispensable service. According to Business Insight, the cloud computing industry grew by 13.7% in 2020. Statistics show that the global industry for cloud computing is projected to reach approximately $1,600 USD billion by 2030 [Precedence Research, 2022]. However, this rapid growth is accompanied by an increase in servers, data centers, and consequently the rise of energy usage therein. Hence, there needs to be a shift of focus on the cloud computing industry not only to help reduce the cost of operations, but also to reduce their energy consumption and their negative environmental impacts, while also improving their economic sustainability. The cloud providers that offer such cloud services encompassing energy efficient technologies with minimal to no environmental impacts are called "Green Cloud Computing Cloud". Moving traditional IT systems to the cloud can save approximately 12.3 billion dollars in energy costs; additionally, with green cloud computing, there can be more savings for energy efficiency [Jena et al., 2016].

Many cloud-based machine learning approaches are used to develop predictive models for effective energy consumption. For instance, smart meters, sensors and other communication networks are installed in buildings to obtain real-time data stored in cloud environments. The stored data is then used to implement prediction models to analyze existing data and estimate future energy usage. This can help with the optimization of energy usage through machine learning algorithms that can analyze energy usage patterns and identify prospective situations when there can be reduced consumption of energy in the future. Several such approaches have led to measures being taken towards energy efficiency and optimization.

In a comparative study on basic cloud computing and green cloud computing, it has been found that as companies migrate towards the cloud for cost and energy efficiency, more data centers are being created which in turn require more energy. As the data centers have large servers which require cooling 24/7, people often question the sustainability of cloud computing. Free cooling of data centers can be a possible alternative in some situations but not always. In line with this, free cooling and its effectiveness in maintaining data centers is explored through much analysis utilizing web data and machine learning techniques, effective for a long time now [Pawlish et al. 2010]. Moving things to the cloud might be better for the carbon footprint of a given company, yet it is vital to quantify the energy used by the cloud provider per se in this migration. Fig. 4 exemplifies the amount of energy consumed in a normal Google search [Jain et al., 2013; Farooqi, 2017].

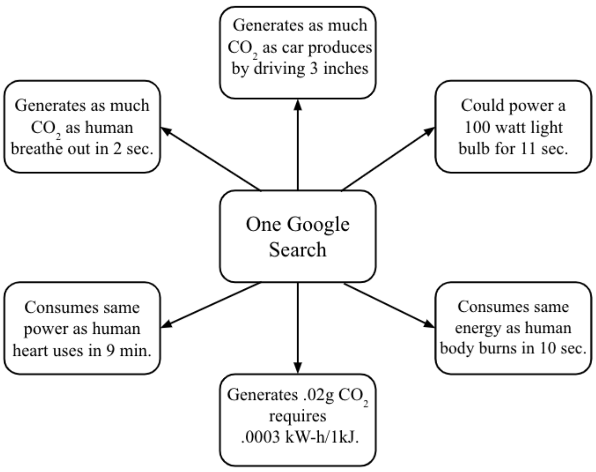

Fig. 4: Energy consumption in a typical Google search [Jain et al., 2013]

As cloud computing helps reduce the carbon footprint and energy usage, there are studies that further focus on the topic of greening data centers, as these are actually the core consumption of energy in this sector. In an interesting study about data centers [Pawlish et al. 2014], cloud-based, server-based and hybrid approaches for data centers are analyzed using the techniques of decision trees and CBR (case-based reasoning). The overall aim of this research is to make data centers "greener". The researchers here focus on various options in the free cooling of data centers through monitoring temperature and humidity, maximizing the server utilization and deploying cloud computing at different levels. This work exemplifies how energy consumption and carbon footprint can be lowered by harnessing CBR methods. It deploys the classical R4 paradigm in CBR, i.e. a 4-step cycle of Retrieve, Reuse, Revise and Retain. The R4 CBR is adapted in this research by testing hypotheses to discover relationships between outside air temperature and energy usage, as well as those between utilization rates and electrical consumption. Fig. 5 demonstrates a good CBR example indicating how migrating some email processes from servers to the cloud in a typical mid-sized university data center can enhance the overall power usage effectiveness (PUE). By using the knowledge discovered through such studies, a GreenDSS (Green Decision Support System) is implemented with the goal of helping to reduce the energy usage and carbon footprint. The vital role of cloud computing in this project is elaborated in another piece of work [Pawlish et al., 2015]. The GreenDSS and the entire setup is found to be effective in practice as observed in a real university setting.

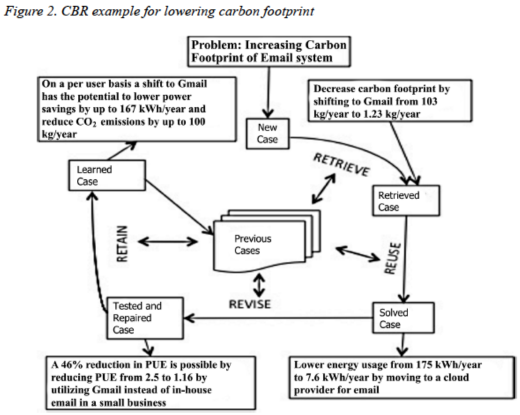

Fig. 5: CBR example for lowering carbon footprint in mid-sized data centers [Pawlish et al., 2015]

An experimental case study is conducted on the campus of UC Berkeley through their Building Operating System Services Platform (BOSS). In this study, a personalized web-browser based personalized lighting controller (PLC) is developed to automate the lighting control system in a traditional commercial building. Instead of using traditional wall switches, users share a virtual switch. This application allows the user to view real-time energy consumption on their floor and use automation to turn on the light switches. The researchers' focus with this program is to reduce energy consumption by diminishing brightness and turning the lights off when not in use, automatically. The results of this case study reveal that the use of this application helps to save 50% to 70% of the total energy [Krioukov et al, 2011]. Fig 6. shows the breakdown of energy usage and savings achieved due to this study. Although this is an effective study that corroborates how automation and monitoring can help reduce energy consumption, the overall discussion on the long-term goals for this project are very broad. The authors do consider expanding the study, but do not mention the scale of such expansion and/or its contribution towards addressing the bigger issue of energy overuse.

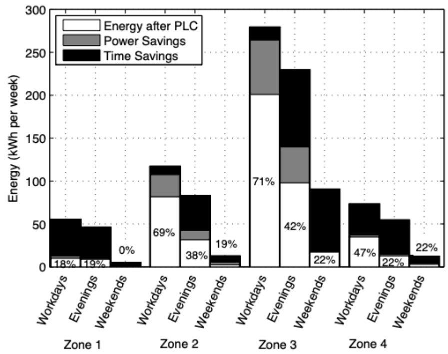

Fig. 6: Breakdown of energy use & savings in buildings in a UC Berkeley study with a PLC approach. Full bars depict baseline weekly energy use before PLC. Shaded regions show sources of energy savings. White bars show weekly energy consumption after PLC, labeled with % baseline energy [Krioukov et al., 2011].

4. OPINION MINING ON COMMERCIAL ENERGY EFFICIENCY

Opinion mining is an important paradigm to help in gauging the attitudes and reactions of people in a multitude of contexts. Gearing towards energy efficiency in commercial settings, opinion mining can offer useful insights into people's beliefs about energy efficiency in commercial buildings, the manner in which they perceive the benefits, and the variables that impact their own decisions. This is in line with multiple studies conducted about opinion mining from social media on various environmental issues, as mentioned in a recent survey article [Du et al. 2019]. For instance, it is interesting to observe why certain people would accept or reject a certain scheme, product or service by evaluating textual data from sources such as online user reviews on specific websites as well as social media posts on Twitter etc. Opinion mining is thus rightly known as "aspect-based sentiment analysis". It provides more granular information about the opinions related to words and the attributes of the text, over and above polarity classification. As well known in the web community, polarity classification provides "positive", "negative" or "neutral" labels based on the confidence scores between 0 and 1 for each sentence / phrase being analyzed [Pang and Lee, 2008]. Since opinion mining can help identify common themes and sentiments, this can be used to investigate some aspects of energy efficiency in order to understand the feelings of the consumers about energy efficient schemes, products or services. It can thus assist the government, companies, and other stakeholders on improving the concerned policies so as to better meet the needs and preferences of targeted consumers. Gauging public opinion on energy policy and initiatives can possibly encourage various governmental subsidies for renewable energy, mandates for building codes in energy efficient design, and other such developments that could be the need of the hour. For instance, there is much emphasis today on LEED certification for buildings where LEED stands for Leadership in Energy and Environmental Design. Many co-operative housing societies (co-ops) and other residential apartment complexes often cost more in terms of ownership as well as rentals due to LEED certification, however, many buyers / tenants happily pay the additional amounts due to numerous environmental benefits that obviously imply improved health standards. Such developments can thus support decision-making and promote effective communication in the context of energy efficiency. This can inspire further work on the use of renewable sources of energy in commercial areas by identifying key drivers and monitoring the public opinion on them. In this context, Fig. 7 synopsizes sentiment analysis of online data based on governmental policies to offer recommendations, as revealed in an interesting study.

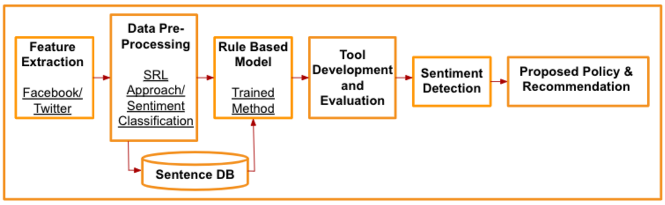

Fig. 7: Conceptual model for sentiment analysis on governmental policies [Hasbullah & Wan-Chik, 2015]

In recent research [Kim et al., 2021], opinion mining occurs on the public sentiment towards solar energy. The authors analyze the opinion of the masses using data from Twitter, collecting tweets across various demographics and geographical locations. They use the RoBERTa (Robustly optimized Bidirectional Encoder Representations from Transformers) model for domain-specific sentiment analysis [Liu et al., 2019]. This is then used to examine the energy market, solar energy policy and public sentiment towards solar energy on a statewide level. It is noticed that the public opinion on solar energy varies extensively across different states in the U.S. This is illustrated in Fig. 8 which shows how the sentiment towards solar energy drifts across the United States from 12th January to 31st December 2020. The average sentiment score in the tweets varies from -10 for tweets classified as negative to +10 for those classified as positive. A correlation is found between the sentiment with RPS targets, consumer-friendly net metering rules, and a more mature solar market in the state. Based upon this detailed study, the authors offer suggestions on policies to address spatial disparities for solar energy, thriving on support from the public regarding this matter, and highlighting possible future opportunities. Lastly, they emphasize the benefits of using social media as a source of data collection for gauging the opinion of the general public, and the use of RoBERTa for this purpose.

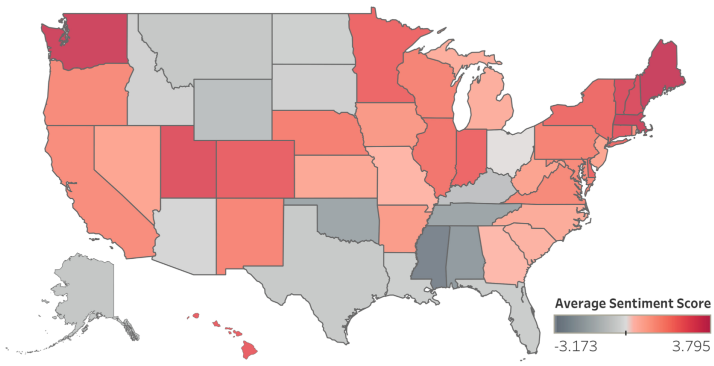

Fig. 8: Spatial patterns in sentiment toward solar energy across the United States [Kim et al., 2021]

Likewise, another study is conducted [Malekpour Koupaei & Cetin, 2021] in order to understand the perspectives of landlords and tenants about smart thermostats in rental housing units. This work harvests the reviews of current buyers and users of smart thermostats in rental properties through the popular online retail website Amazon.com, based on the housing tenure status. These reviews are then qualitatively and quantitatively evaluated, comprising sentiment analysis of the users' views associated with each of the predefined topics. Smart thermostats help with energy efficiency as they are controlled by the given users via the Internet; they can thus help reduce the use of energy, based on the requirements. Understanding the energy and non-energy related opinion on smart thermostats in the rental housing market can help in delving into the motivational factors about the devices being used by the consumers in this market. This can enable better targeted efforts to encourage the adaptation of energy efficient technologies in rental housing units by comprehending the public perception of the concerned technologies thus far. This study unveils that the consumer reviews are much related to the price of the thermostat, and that the trend of smart thermostats in the rental housing market is gradually increasing. The trend is therefore predicted to increase in the future as well. The results of this study further reveal that landlords have less incentive to invest in such technologies for energy efficiency because doing so does not increase their profit. This study is crucial in demonstrating the actual application of the sentiment analysis as per understanding the feelings of residents in housing units and their reception of energy efficient technologies, along with the factors that affect their opinions.

In another piece of work [Loureiro and Alló, 2020], Twitter conversations in Spain and the U.K. are analyzed to assess the awareness and concerns towards climate change and energy related matters. The authors conduct international comparisons about emotions and sentiments on climate change and energy issues expressed in different languages using NLP (natural language processing) tools. Results of this work indicate that there are more negative conversations in Spain than that in the U.K. regarding this topic, whereas renewable energy on the whole is viewed quite positively in both places. Fig. 9 here shows four different word clouds to highlight the most predominant topics in a corpus of text. The tweets in the U.K. are less negative towards climate change compared to Spain, which reflect the attitudes towards climate change among the respective masses. This study emphasizes that learning about the opinions of people on certain topics can help in gauging the severity of the addressed topics.

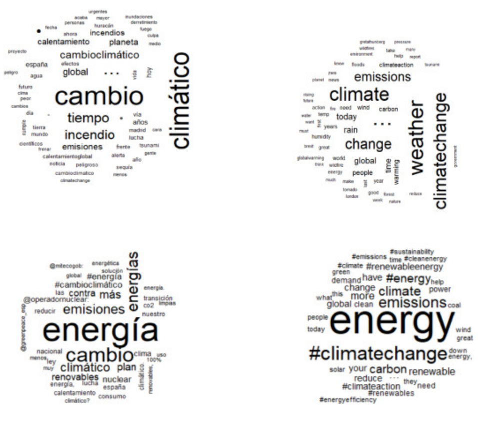

Fig. 9: Word clouds from Spain and U.K. pertaining to climate change and energy efficiency (Upper: general climate change conversations; Lower: energy related conversations) [Loureiro and Alló, 2020]

These are just a few examples of research on opinion mining / sentiment analysis to fathom the mood of the masses towards several energy related topics, and envisage how it can be useful to the market sentiment vis-à-vis stakeholders and governments for outlining relevant strategies and policies. This in general fits the realm of smart governance where it is important to endow more transparency in decision-making via greater involvement of the common masses. There are many studies conducted in these areas, e.g. [Gandhe et al. 2018] on learning from partially labeled data to conduct sentiment analysis in various applications including environmental issues, and [Puri et al., 2018] on mining from ordinances or local laws, mapping them with their public reactions expressed as tweets via a nexus of smart city characteristics. However, in general there is a dearth of studies on mining mass opinions pointed specifically towards energy efficiency and related matters. The results discovered from such opinions can often provide crucial information to stakeholders. Hence, this offers the scope for further research. Likewise, works on IoT, smart manufacturing and cloud computing present open avenues for future work as well. This brings us to a general discussion along with potential open issues.

5. DISCUSSION AND OPEN ISSUES

Improving commercial energy efficiency is an important step towards a more sustainable future. Reducing energy consumption and carbon footprint in the sector that accounts for about one third of the total energy consumption can help not only to conserve natural resources, but also to improve the overall health of the planet by enhancing air quality, saving costs, and encouraging sustainable practices. Although the significance of the web and energy consumption is well recognized by academia, industry, and governments, there is a dearth of substantial efforts towards the overlap of these sectors. There are several matters that need to be addressed, putting forth open issues in order to enhance the adaptation of IoT, cloud computing, and opinion mining for improving energy efficiency in commercial settings. We mention these briefly.

Detailed cost-benefit analysis: The cost of multiple advanced technologies is a key factor. However, this can raise a few questions, e.g. as follows.

- Does reducing the cost of energy consumption definitely improve the overall sustainability in the energy sector?
- Can the reuse and recycle of materials be crucial in cost-related decisions?
- How does this compare with cost and energy issues in related sectors?

Such questions can offer the scope for further work, e.g. in terms of materials science, manufacturing technologies, engineering advancements, transportation sector versus residential sector comparisons and so forth, some of which have been addressed in our own research teams [Varde et al. 2023, Prasad et al. 2021, Singh et al. 2022, Varde et al. 2022]. Much of this needs to be investigated more in conjunction with web-based data. On a related note, conducting sentiment analysis about people's views on smart manufacturing can help gauge the opinion of traditional and modern factory workers, which can be incorporated in detailed cost-benefit studies to gain more insight.

Citizen science: Identifying the gaps that exist and noticing the aspects that might get ignored in expert scientific communication can then be implemented into decision-making processes by the government through mass opinion. This is important in terms of a growing paradigm called "citizen science" where common masses can participate in various tasks such as data collection, implementation of processes, and evaluation of outcomes without being experts on specific topics, even if they are novice users. For instance, residents of given localities can submit useful data through handheld devices, home gadgets, and mobile apps for the government to use in decision support on various schemes, or for researchers to use in scientific analysis. Some of this can be crucial information pertaining to urgent issues such as disaster and recovery. Other information can include data on regular household matters that need long-term attention, e.g. pet policies in buildings, smoke-free zones in cities, and so on. Citizen participation is truly valuable here, which calls for more research to facilitate it.

Human-robot collaboration: HRC or human-robot collaboration is a paradigm that entails humans and robots co-working and complementing each other (rather than only humans / only robots working on tasks). This is an important topic, mentioned in many research works, e.g. on smart manufacturing [Conti et al. 2022]. HRC needs much attention today because it brings the promise of human beings and robotic systems working hand-in-hand so as to bring out the best in each other, thereby improving overall outcomes that can often be better than either one working alone. Therefore, HRC has the potential to improve not only the energy efficiency and the cost effectiveness of the manufacturing industry but also the living standards of the workforce, especially in terms of human safety and comfort. This paradigm should be further investigated, considering smart manufacturing, IoT, and opinion mining.

Cyberlaw and related aspects: Studies on increasing the overall accuracy of opinion mining are imperative. Issues such as ensuring data veracity [Krotofil et al. 2015], mitigating fake news proliferation [Ho et al. 2022], investigating hate speech detection [Kommu et al. 2022] etc. are highly significant and need to be addressed, especially with reference to context. Some of this research might possibly be domain-specific, encompassing energy management, while much of it pertains to web-based data and social media. Accordingly, there could be a need for stricter measures about the accessibility to people on various social media sites, the associated privileges as well as constraints, including the adequate and fair enforcement of cyberlaw as needed. While some of this is already being addressed, there is scope for more work here.

Diversity & inclusion: A vital but oft-ignored or downplayed area is that of diversity and inclusion (D&I). This is significant because many people who may be adversely impacted using commercial technologies may not have adequate access to the web for expressing their opinion. For example, a commercial facility such as a factory in an automobile industry may release severe pollutants into the environment in a neighborhood where people may not have enough potential to use the web and social media. Hence, other means need to be deployed in order to garner data from such communities in line with EJ (environmental justice) policies. In the U.S. such groups typically consisting of low-income neighborhoods are referred to as the EJ communities. For instance, a recent policy in New York City mandates Internet service providers to offer drastically reduced prices to "very low income" households because the Internet has been deemed as an essential service today. While such initiatives can possibly be the result of social workers expressing their opinions and actively voicing their concerns, there is still the need for more active enforcement. Much work in this matter can pertain to addressing opinions of people who are:

- not active social media users (e.g. by choice)
- with limited computer literacy / not tech-savvy (e.g. due to age)

- from low income groups with lack of Internet affordability (e.g. EJ areas)
- affected by accessibility issues (e.g. visually impaired)
- web users in an uncommon language of the area (e.g. Cantonese in the U.S.)

It is important to address the opinions of all the masses for more inclusiveness, along avenues such as: encouraging more people to become social media users while also addressing veracity concerns; offering more automation in Internet-access, especially for very senior citizens; conducting outreach activities in multiple locales e.g. EJ communities for helping them to directly voice their opinions online; promoting advances in text-to-speech and speech-to-text assistance for some people with special needs; proffering seamless language translation with semantic reasoning for a plethora of multilingual users, and so forth. Many such avenues present challenging research.

Overall, the web is a boon in various areas, and commercial energy efficiency is no exception. While there is huge potential in the areas of IoT, cloud computing, and opinion mining for improving energy efficiency in commercial settings, there are still multiple gaps that need to be addressed through continued research. This will be the key to understanding the full potential of a myriad of technologies to improve energy efficiency for achieving a more sustainable commercial sector.

6. CONCLUSIONS

This paper presents a survey that explores the overlap between various applications of the web, and how the web can be used to achieve efficiency in terms of commercial energy consumption. It presents an overview to examine web technologies in conjunction with machine learning, and their applications towards energy efficiency and environmental management. It highlights practical examples of studies that can help automate and personalize the use of energy, and emphasizes how modern technology can lower the use of energy and promote environmental sustainability.

It explores the area of industry 4.0 or the fourth industrial revolution where automation and use of IoT can help make manufacturing more efficient, and reduce the energy wasted in traditional manufacturing practices. It investigates the related realm of smart manufacturing where systems can help monitor energy usage in real-time, find abnormalities in energy use, and observe where energy is being wasted, in order to make future decisions to help optimize energy usage. Such technologies can help with predictive maintenance, energy monitoring and management, which in turn can also make the commercial sector more energy efficient. The use of cloud computing, and the importance of greening data centers in this ever-growing digital world with its energy exploitation, is discussed in this paper as well, along with a few solution pointers. Lastly, opinion mining is addressed with respect to its advantage in understanding the opinions and sentiments of the consumers and other stakeholders in the sector of commercial energy. This is crucial in terms of tapping the specific needs of targeted users and enabling the government as well as other decision-makers to tailor their policies and strategies accordingly.

As we explore prior research in these areas, we find the scope for future work. We discuss many open avenues for further research accordingly. In general, we notice that there is a greater need for cross-disciplinary research across the technologies overviewed in this paper. Moreover, there is not enough literature on opinion mining in the energy sector per se. Hopefully, as the world moves towards energy efficient technologies, there will be more studies conducted and the results of the research will be applied in real-life scenarios. Much of this work will help to create a more sustainable environment with broader impacts on smart cities and a smart planet. Our paper therefore provides the two cents here, making a modest contribution.

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