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Chapter 6: Exploring the role of artificial intelligence in driving automation and innovation in smart energy and smart campus ecosystems

6.1 Introduction

Nowadays, artificial intelligence (AI) technology is paving the way for adding value and benefits to the world. AI is capable of solving complicated problems and providing multiple applications and solutions. The Internet of Things (IoT) is also playing a significant role in today's world. IoT covers a wide range of devices, software, actuators, and systems that all function to provide and share data collected from a wide range of richly interactive applications. IoT technology has a vast and essential role in a smart campus or smart city. IoT is one of the main technological approaches underpinning a smart campus. It helps in gathering, sharing, and analyzing real-time data so that buildings and grounds can optimally operate. Similarly, the smart energy (SE) ecosystem is capable of exchanging information and is also capable of self-diagnosing to find useful data and outcomes from different stakeholders; however, the lack of a standard and searchable structure for this information sharing limits its usage and the value for both the stakeholders in the SE ecosystem and the revolution of future business models. This research study underlines the potential roles and impacts of AI technology towards the commercialization and full development of SE big data and also indicates the possible research gap and future trends in the field.

6.1.1. Purpose and Scope of the Document

Energy management and facility modernization/campus asset management are ongoing challenges at large, diverse campuses. Renewable energy production and smart building/smart energy management provide opportunities to address these challenges but require automation and digital platform evolutions. Meanwhile, technological advancements have seen increased use of emerging frameworks and tools such as machine learning and artificial intelligence to solve a variety of complex economic and engineering problems at different sites and operating conditions. We are exploring the full range of applications of AI, data-driven predictive frameworks, integrated controls, and cloud-enabled solutions across smart energy, renewable energy, and automation of different complex applications, including automation serving the unique needs of a university or a technology-rich urban campus. We are looking for individuals and teams and associated use cases across university research industries and organizations in our educational system, as well as university partners from other countries with similar challenges and priorities.

The main purpose of the document is to provide brief background information on AI topics, describe a general process approach to technology adoption and upgrades in the energy value chain, and relate these technology elements to relevant generic attributes of a Smart Energy and a Smart Campus Ecosystem. The information provided will be helpful for scoping research proposals, project considerations, workshops, and exploring topics for development including curriculum, market intelligence, emerging applications, unmet challenges, and workforce accumulation and training efforts.

6.2. Understanding Smart Energy Systems

It is important to understand that a Smart Energy System (SES) comprises not only the collection of numerous smart energy substations and smart energy specifications present in and around an energy facility but also the cloud-based analytics and applications that promote achieving situational awareness and operational intelligence with the manpower available. Most modern-day energy facilities are sizable and complex, requiring personnel, staff, and community stakeholders to manage the equipment and processes. Inherently, by integrating modern digital and communication technologies, a smart building, smart campus, or smart utility, such as a water treatment facility or a hydropower plant, can support enviably "smarter" energy usage. As advanced techniques from artificial intelligence (AI) continue to evolve and establish their places in the information era, it becomes beneficial to consider the possibilities of automation from a different perspective. The prospective contributions that one can expect from a systems engineering perspective are truly multidisciplinary, impacting not only hardware development and deployment but also encouraging advanced analytics and relevant use-case exploration. The numerous entities within a smart energy ecosystem are often connected by cookies and metadata sharing activities.

Fig 6.1 : Smart Energy System and Its Disciplinary Teaching Reform Measures

The key players within a smart energy system are the smart buildings and facilities, the smart devices and appliances, the consumers of smart energy services, the smart meters that keep track of energy specifications and data flows, the edge gateways and other edge devices that often augment decision-support activities and handle communications, the servers and clouds that store and process the big data collected and generated by the energy activities, the energy supply chain and the grid services that allow semi-automated and automated resources to be brokered within the smart energy system, as well as associations, standards, and regulatory bodies that influence how energy specifications and sensational data can be created and shared between the numerous energy players. Simply put, an ecosystem is a synergistic combination of all the entities that interact with any given energy system to manage energy consumption across the hybrid energy supply chain. Within a smart building, fusion can combine tactile envelopes with smart electrical, smart lighting, biometric adaptation, plug-in electric vehicles (PEVs), and connected devices. Building intelligence describes the evaluation and management of a building to reduce its total cost of ownership, boost its efficiency and sophistication, and to output long-term sustainability with more comfortable living and working on the inside. Buildings are estimated to account for 76% of the electricity in the U.S. It is the intent to provide Smart Energy services to the people and places working within the buildings.

6.2.1. Definition and Components

Modern campuses and their surrounding smart energy ecosystems come with a high level of interconnectivity and complexity involving a large number of diverse components, including energy generation and storage. This definition involves learning and decision-making. It seems that artificial intelligence can play a key role in contributing to effective functioning and performance optimization, including managing and solving the associated challenges and issues. In fact, smart, sustainable, and modern campuses are now proactively integrating the latest in cloud computing, edge processing, and artificial intelligence to help manage and optimize energy usage. In addition to demanding convenience, similar to smart cities, campuses have the associated environmental, societal, and economic pressure to not only reduce carbon emissions from power generation and transportation but also to optimize their total energy usage and usage peaks. The campus's energy generation and storage facilities will need to be smart and flexible enough to adapt to the dynamic changes in energy balance, especially at peak times. There may be some requirements for demand-side energy management through economic incentive response. In this situation, in addition to designing buildings and vehicles to consume less energy, artificial intelligence deployments can further help in learning and predicting energy demand to control and manage the associated supply-demand balance.

6.2.2. Current Trends in Smart Energy

Smart Energy has been evolving due to the increasing integration and monitoring of ICT with electricity supply and usage assets. There are several layers in the smart grid including consumer, DMA, DSO, transmission, and generation. Advanced metering, demand-side management, and systems to improve operational efficiency in generation, transmission, and distribution, decrease tariffs and so on, are some of the smart grid initiatives to address energy-related issues around the globe. The expected benefits include: a) that it enhances customer experience and engagement, b) it provides new opportunities for suppliers and third parties, c) it provides the foundation for the low carbon energy system, and to varying extents, it offers a wide range of benefits for national policy.

Advanced metering infrastructure (AMI) is the technology that measures, collects, and analyzes energy usage, and from which the utility can offer two-way communication with the meter. The objectives with the use of AMI include achieving operational efficiencies and improved demand response by collecting time-of-use data, which can be used for real-time pricing as needed, and which has emerged as a key benefit of the smart grid. AMI offers a more reliable power operations and management system. This can be reinforced by remote monitoring, control, and thermostatically setback of HVAC units. AMI can also reduce operational and maintenance costs and billing by automatic meter reading. AMI operational efficiencies provide higher quality services and better customer service. AMI offers two-way communications and provides smart meter optimization potential. It can also reduce the outage and restoration time, support consumer energy use, and upgrade system security. AMI is a major component of the smart grid. The use of AMI provides potential economic, social, and political benefits. Economic benefits are obtained by improved software for the utilization of the AMI system. The standards necessary for AMI operations and management may require new standards or extensions of existing ones. The required policies for technology implementation are also fulfilled for the deployment of AMI. AMI technology can be used in every part of a smart grid. The benefits that are obtained with the use of AMI are increasing every day. The savings are possible because of the functionality of AMI that is built into it. The functions include data collection, consumer and cost control, automatic price optimization, operator control, response to demand forecasts, and ensuring efficient operation of electrical grids. AMI will gain its strong influence in every progressive country and city in the near future.

6.2.3. Challenges in Smart Energy Implementation

Implementing smart grid and smart energy solutions in the last mile involves more challenges. Integration of smart energy systems with devices inside buildings needs sophisticated energy management, simulations, and demand management technologies. Multiple-tenancy issues arise in the context of heterogeneous stakeholders' involvement and real-time pricing documents. Main barriers in many cases are related to regulatory compliance and retailers.

Additionally, demand response is exponentially increasing and has a direct impact on the electricity network to supply more energy when requested by the power grid. Managing multiple independent stakeholders to provide demand response at city or campus scale is challenging. Research continues at the regulator level to facilitate two-sided markets and implement new types of energy efficiency and demand management programs at city, campus, and building levels. Such efforts often call grid connection codes into modification, as the current ones often have specific requirements related mainly to security, safety, and privacy, meaning they are not friendly for microgrid interaction.

Smart energy systems involve a broad spectrum of stakeholders that need to collaborate, including distribution network operators, transmission network operators, energy service companies, aggregators, retail markets, demand response coordinators, and facilitators of new energy-related services relying on energy sector democratization. They should collaborate to ensure that they not only retain the ability to change business models from centralized ones, by which stakeholders are mere energy buyers, to 'prosumers' scenarios, where the consumers are also energy sellers, providers, or even aggregators. They need to redefine the relationship that links the electric power system with the complexity and diversity of the customer base, ensuring their role in the operation of interconnected power systems, in a context of decentralization of resources that, until recently, were only controlled by the distribution networks. They should facilitate multi-sided relationships and ensure that decentralized systems operate as safe and efficient technologies.

6.3. The Concept of Smart Campus

Definition of Smart Campus

The term "smart campus" has become well recognized and accepted as a specific application of the smart systems paradigm. Beginning with the definition of "smart campus," we carefully selected the keywords from a number of mandatory features. The campus ecosystem covers different venues such as universities, offices, shopping malls, parks, and schools, while the smart campus is about making everything successfully interact in a highly dynamic environment to offer excellent services. The objective of a smart campus environment is to provide an intelligent, safe, comfortable, efficient, and networked atmosphere for the inhabitants. Different from the traditional ICT system, the smart campus should be an organic whole, which consists of intelligent perception, public networks, cloud computing, intelligent decision-making, and support systems.

The feature of "intelligence" indicates that various terminals of some specific applications such as office automation, class teaching, hospital treatment, personal service, freight handling, and cable distribution are required by the intelligent perception function. To this end, the perception infrastructure should be able to acquire, identify, and analyze information such as the movement of students, the position of cars, energy consumption, CO concentration, as well as the real-time status of air conditioning, lighting, smoke, rainfall, garbage levels, etc. The public network is an important support for the smart campus ecosystem. On the one hand, the building-in network should be able to provide maximum support for daily operations. On the other hand, the external broadband network should support a variety of real-time data exchanges and remote services. Under information interaction, cloud computing can provide students and faculty members with useful application services using cloud platforms.

6.3.1. Defining Smart Campus

The term "Smart Campus" refers to the modernization of the traditional campus by leveraging innovation and cutting-edge technology that will enhance the workplace environment, optimize campus operations, and connect the students, faculty, and staff of a college or university like never before. In recent years, the utilization of artificial intelligence and machine learning in developing modern smart campuses has significantly increased in conjunction with the expansion of the practical applications of smart devices and Internet of Things technology. Smart devices provide campuses the ability to collect and analyze data, and artificial intelligence and machine learning methods are perfect for using the data to develop models to make data-driven decisions. Priorities of the modern smart campus may cover, but are not limited to, a variety of focus areas such as accessibility, aesthetics, collaboration, security, sustainability, partnerships, standards, and interoperability.

The focus of smart campus efforts is to collect data needed to make intelligent decisions. Models are used to analyze the data and provide improved intelligence to act on. An example of an IoT device providing data for the smart campus is an occupancy sensor. When hooked into the campus infrastructure, the sensor can be used to monitor and report occupancy of a building, creating a map of when rooms of the building are in use. When mapped around campus, these points in aggregate can produce a model of campus activities and show patterns in the use of spaces. Providing the data and traffic patterns of campus buildings allows for better scheduling of classes while optimizing the utilization of the classrooms.

6.3.2. Key Features of Smart Campuses

A 'smart campus' leverages the strengths of technologies in integrating and connecting research, teaching, maintenance, and development of resources and services, and emphasizes innovation, practicality, flexibility, and interactivity. Key features may be related to the size of the campus and the diversity of its facilities. Universities located in remote, geographically unique locations provide special research opportunities and help provide students with not merely a living and studying environment, but also an interactive recreational environment with nature, as such a unique geographical environment can provide the basis for diverse academic research and studies. High-tech research often requires extreme environmental conditions that these kinds of unique natural features provide. This is one demand for the smart campus. At the same time, schools can use these unique features to attract faculty, attracting outstanding researchers and then letting information lead to high-level education.

Artificial intelligence smart applications connect people, such as intelligent dormitories, hospitality, and teaching with various combinations of IoT technology and AI capabilities, so that some problems can be solved both efficiently and punctually, providing a more realistic perception. Similarly, a smart campus system for teaching and learning in combination with intelligent recruitment, class scheduling, and tutoring apprenticeship mechanisms supports smart dormitory systems. In other words, such a range of AI intervention strategies may present students with different interdisciplinary learning environments, mutually assisting and promoting the growth of learning efficiency. Through teaching, campuses can offer students practical and interactive experimental methods, using machine learning, natural language processing, speech recognition, gesture recognition, human-computer interaction stimulus-based applications, and educational and teaching applications such as virtual reality and augmented reality. With tutoring, the smart campus teaches students how to learn, relieves stress, and provides diverse social information as well, allowing students to grow individually and socially in a happy living environment.

6.3.3. Benefits of Smart Campus Initiatives

Higher education institutes are at the forefront of innovation and research. Consequently, they represent a strategic innovation point to generate new knowledge on how to better manage energy demand, supply, and the lifecycle of the buildings and facilities that compose the smart campus ecosystem. The benefits of deploying specific solutions in higher education campuses range from student and staff safety and well-being to operational efficiency of the academic estate, or tangible benefits in meeting environmental sustainability targets. Universities have become increasingly interested in exploring ways to become more sustainable and green through improving energy productivity, decreasing energy consumption, and optimizing energy use. This can be particularly challenging, not only for the sheer variety of different campus types but also because of the combination of different buildings, infrastructures, and installations that need to be managed sustainably.

A wide range of smart campus initiatives can lead to a variety of benefits. Benefits can include areas such as well-being, comfort, mobility, and social interactions, but also more specific areas such as safety and security, flexibility, or adaptation of functions depending on the specific time of the day, the specific period of the academic year, or the specific weather conditions. Such initiatives also involve benefits linked to operational efficiency and educational objectives. In addition, of interest are benefits related to energy efficiency and the decrease of greenhouse gas emissions. With such varied initiatives come also different stakeholder perspectives, which include academics, university staff, and the students themselves. With this heterogeneity of potential benefits, proposing an innovative smart campus solution and convincing the stakeholders to adopt and use it is not a simple task.

6.4. Artificial Intelligence: An Overview

Artificial intelligence (AI) examines computational models of intelligence that can be embodied in machines, including robots, automated systems, and software that can perform cognitive tasks. This includes the ability to apprehend emblematic and numeric information, to deduce from such interaction, to learn from examples or from direct experience, to ground decisions in context, to adapt to change, to create explanations for users, to communicate naturally, and to take coordinated action. Throughout the past six decades, AI has developed two decision classes: model-driven versus data-driven, with the former employing methods such as expert systems, planning, and optimization, while the latter uses approaches such as machine learning, neural networks, reinforcement learning, and deep learning. Model-driven AI requires human experts to develop rule-based models using information about the application problem and the rules that link together the entities. Problems with model-driven AI include the need for a lot of domain-specific knowledge, significant use in training and human expertise, and a lack of generalization to novel situations. In contrast, data-driven AI examines data from various sources.

Machine learning uses data to populate statistical models and algorithms to give computers the ability to learn with no immediate need for rule-based models. Examples include the automatic tabulation of text, natural language processing, and image and speech processing. Machine learning is primarily used to recognize patterns in a dataset and is carried out by classification, regression, clustering, and ranking algorithms. Neural networks seek to imitate the human brain by having neuron-like structures. The network is organized with layers of neurons, including the input layer, which takes the initial data and transmits it to the hidden layers, and the output layer. The hidden layers contain one or more interconnected nodes, which in turn have a value based on the weighted relationships between the nodes in the previous layer and an incremental node-specific bias. The last layer of hidden nodes communicates the resultant value to the output layer. The initial neural network model determines the initial system, and it is updated by modifying the weights to repeat the tasks needed to improve the model's correctness.

6.4.1. Definition of Artificial Intelligence

The concept of AI entails smart machinery that can copy human operations by conversing and foreseeing, while not thorough or definitive, about differing aspects of human information using computational processes such as reasoning and self-correction. Examples include robots that understand the layout of houses, cars without a driver, and systems that analyze a great quantity of information to decide whether to increase the stock or move the machinery. Usually, there is not one established meaning of AI. From a broad point of view, AI is roughly identified as machines designed to carry out activities independently according to perceived rules, for instance, machines speaking and predicting. These characteristics have induced various thinkers and experts to project hard tools and intelligent machinery that, even if they don't always copy humanity's knowledge with every feature, are able to perform similar activities by using arithmetic and computing processes, often much more efficiently than people. Consequently, AI plays an influential role in the disciplines of creating alterations in the technological footprint.

To elaborate further about AI, there are individuals who initially define and describe AI following the Turing test. However, the Turing Test is a mental experiment proposed to illustrate the feasibility of considering a machine to possess an AI, which is produced by a human and then tries without success to distinguish it from a human. The underlying assumption is that a machine able to simulate the performances of a human in such a way as to lead another human to confuse it with a human might also be considered intelligent.

6.4.2. Types of AI Technologies

AI can be classified into several categories depending on the system's behavior, such as knowledge representation, reasoning, and learning, or the type of learning process, such as supervised, unsupervised, or reinforcement learning. The major types of AI technologies are expert systems, including knowledge-based systems and rule-based systems, learning systems such as supervised, unsupervised, and reinforcement learning, and analytical systems such as cognitive systems, which possess specific cognitive abilities characteristic of human minds. The knowledge-based and rule-based systems are more commonly used in smart energy and smart campus ecosystems. They allow the capture and use of fuzzy and heuristic knowledge, which has significant advantages in the development of intelligent automation and innovative solutions. Knowledge-based systems use a set of rules, inference engines, and knowledge bases to support complex decision-making processes or automated reasoning. The rules or logic are formulated through knowledge elicited from experts.

In recent AI research trends, deep learning and big data are considered suitable mechanisms for enabling intelligent tasks and improving learning algorithms in various fields. They are instrumental in enabling the continuous learning of more accurate AI models and the effective utilization of big satellite datasets to produce more precise results. Another popular AI technique is online AI, which features real-time learning and feedback generation in an effort to enhance customer satisfaction, service customization, and business awareness. In addition, smart energy and smart campus ecosystems can take advantage of the latest trends and technical advances in AI to provide more client-appropriate and customization-based applications.

6.4.3. AI in Everyday Life

The third-dimensional construct provides an overview of the role of different AI techniques in various aspects of our daily life. Modern homes, based on smart energy concepts and the Future Internet of Everything, can incorporate numerous AI-driven systems for managing the availability of power, storage devices for improving energy efficiency, intelligent agents capable of communicating the real cost of watts, forecasting the power load per appliance, planning and deciding the operation schedule of the home's smart appliances based on tariffs and personalized preferences, demand response management, cyber-secure protection systems in wireless powered communication, automatic anomaly detection in the normal, daily, and abnormal operation patterns of each smart appliance, within the time domain and regulatory rules design decision support.

Furthermore, AI techniques strategically designed to operate as smart home appliances in the context of a completely smart or cognitive room will significantly simplify the occupant's interaction and control of other home smart appliances and systems, providing them a unique, AI-driven mystery room perception. Personal applications of AI techniques and algorithms for entertainment, information retrieval, opinion analysis, recommendation systems, daily habits understanding, scheduling, organization, memory triggers, problem-solving, consciousness, and general content are also discussed. Finally, the AI-driven tram as a basic transportation means in the smart city context is presented and evaluated within a new path elongation project.

6.5. AI Applications in Smart Energy

The advent of AI and IoT technologies is driving transformative innovation in smart energy by enabling household and small business consumers to become active energy traders capable of both buying and selling their energy on transactive energy markets hosted by emerging energy prosumer business models. The text first investigates several AI-based transactive energy control algorithms that are capable of managing the demand response and energy production-consumption functions for both the P-Consumer and P-Prosumer business models. These state-of-the-art transactive energy algorithms provide the technological foundation for the digital energy provider business models, as well as the socially responsible grid operators that manage more sustainable and environmentally friendly digital energy markets. Transactive Energy Marketplaces are used to coordinate the trading of energy, insights, or knowledge across energy storage devices, smart metering devices, smart IoT-enabled building management systems, controllable thermostats, load shifting and peak load reduction devices, and distributed ledger technology based digital energy trading systems. Households, buildings, small commercial businesses, and larger commercial businesses that choose to install distributed generation and/or storage devices connected to the power grid, and are capable of both buying and selling energy on TEM must be equipped with virtual intelligent agents. Advanced AI virtual agents with the machine learning capabilities enabled by reinforcement learning algorithms, closed-loop automation control, dynamic optimization, stochastic optimization, robust optimization, game theory, logistics optimization, numerical simulation, and real-time performance monitoring and control are used to deliver the coordination of prosumer preferences and grid capabilities that is a necessary condition for scalable TEM operations.

6.5.1. Predictive Maintenance

Predictive maintenance is designed to change the traditional way of maintaining tools and equipment in the industry. Traditional maintenance of the equipment is performed when tools and equipment have already led to damage and loss of function. This traditional way of maintenance incurs very high associated costs. This means that operating costs have increased due to sudden failures, repair costs have increased, production capacity has been reduced due to repairs, spare parts inventories have increased, replacements, and resource management costs.

Artificial intelligence, being a technology that can make predictions based on historical data, greatly facilitates life in the industry by predicting system failures before they occur. Predictive maintenance has many advantages over traditional maintenance, such as lowering costs associated with maintenance, increasing production time, reducing production losses, reducing the likelihood of failure, reducing maintenance downtime, and extending the lifetime of the system. The purpose of the predictive maintenance system is to inform about the time before the equipment failure occurs based on the deterioration of its performance. Thus, the operator has time to remedy the problem, reduce the risk of failure, and in the long run, prevent the failure.

6.5.2. Energy Management Systems

This review assesses the use of Artificial Intelligence in energy management systems as a sub-domain of a Smart Campus. Different approaches have been applied to create energy management systems based on AI and data analytic techniques in a way that caters to different business needs and requirements. The first part of this review discusses the challenges and requirements of a generic energy management system based on AI for a smart campus. The second part presents work developed in creating environments that simulate how AI can provide solutions to fulfilling some of the requirements mentioned in the original part. Finally, it concludes that simplified energy management systems allow current AI methods to be used and justifies the simplified characteristics. The work described in this review can serve as a basis for the selection of specific AI methods for modeling data analytic tasks for creating novel, tailored, simplified AI-driven components, benefiting various application domains that Smart Campuses could benefit from.

Fig 6 . 2 : Energy Management Systems

6.5.3. Demand Response Solutions

Demand response (DR) concerns the flexibility of end users towards the load demand in view of varying energy market conditions. Specifically, in energy-intensive industries, the significance is even greater due to the consequent reduction of energy costs and the attenuation of carbon emission levels, with the participation of these facilities in the short-term services market typically occurring as price-taking units. The establishment of DR ecosystems that manage the complexity of multiple DR schemes towards the degree of responsiveness of the end users, envisioning the potential resulting benefits, is not a trivial task. Machine learning methodologies provide the necessary intelligence features for balancing the trade-off between the bill savings of the end users and the overall benefit gained by the aggregator and the DER.

Several aggregated energy demand applications in the electricity sector pertain to the demand-side management (DSM) philosophy, where the objective is to minimize the utilities' electricity purchases at the wholesale market while considering the stability of the grid network. In this context, the service provider that deploys the DR ecosystem, usually designated as the aggregator, relies on a two-tier transactional model concerning the provision of DR services and the reduction in electricity or capacity charges to the end users. The agents in the upper layer (industrial, commercial, or residential customers) receive incentives to modify their electricity consumption based on global electricity network events. The bottom layer hosts flexible energy resources, the DR models, and the communication infrastructure that enhances the interaction between the multiple entities in the market during any time scale.

6.6. AI Applications in Smart Campus Ecosystems

Nowadays, universities and institutions are turning into smart campuses. These campuses are intelligent in managing resources efficiently, enabling autonomous operations, and delivering data and innovation. They provide a growing set of services to the students, faculty, staff, and the community, including mobility and transportation services, security services, smart infrastructure services, and digital services. Artificial intelligence can bridge the gap to produce plausible and innovative research in this discipline and help smart institutions reach their maximum potential. This chapter provides an overview of the current AI applications in smart campus ecosystems.

The needs of the campus are diverse and evolving. To cater to these various needs, AI technologies can be used to build smart, cognitive systems that can understand, reason, and learn from the information generated and shared by institutions. The campus data is both structured and unstructured. It could be anything from open data, wireless data, social posts, news, and videos. AI and machine learning technologies can understand the data and explore it to understand its value, helping to perform pattern identification, relation and relationship identification, and predicting unexpected circumstances. With predictive analysis and modeling tools, AI systems can forecast energy consumption and predict influx. In addition, campus operators can initiate new analysis on different dimensions to focus on what is best and document the results to command which conclusions lead forward.

6.6.1. Intelligent Building Management

In the context of an intelligent building management scenario, promising AI works exist. The core research themes cover various areas, such as real-time energy and comfort management, adaptive occupancy modeling, predictive diagnosis, and intelligent control, just to name a few. Training data are often collected from various sources, such as energy and power management systems, building management systems, environmental sensors, and IoT devices. Advanced AI methods, such as deep learning, machine learning, clustering, prediction, and others, are effectively applied to solve the diverse problems in this domain. Moreover, various types of buildings, such as residential, commercial, and institutional, have attracted research interests.

Of course, such research benefits smart home and office occupants while leading to more intelligent building systems that could potentially be autonomously managed. In the long run, more sophisticated and AI-infused intelligent buildings can not only tailor to the specific needs and habits of the occupants, with better comfort and, if smart enough, improved productivity. They can even assist the occupants to the maximal extent in preventing health risks via environmental optimization, online tracking of health information, and adaptive environmental control. These beneficial AI applications highly motivate further development of intelligent building management in the future.

6.6.2. Campus Security Systems

In colleges, class attendance is mandatory for students. We assume that students attend the classes according to the schedule. For that, we built a face recognition system that can recognize the students. As they enter the premises, their images are automatically captured using a camera placed at the entry gate and recognized. Attendance is captured just when students depart from the premises. Thus, we must consider threshold time and update the attendance hours. The student records, including images, are displayed in a form on the same webpage, which can be edited in the occurrence of false recognition. When the student shifts from one classroom to another, a system will display any text or an image with the shift button, but the arrival and departure buttons will not appear. Consumers worldwide are beginning to realize the value of video surveillance. The college is no different. Given the incidents of vandalism and a changing environment at a college campus, the visual being built becomes an attractive security feature for schools. Also, the students can monitor their potential attendance as they can throughout the day, as parents and students are always concerned with safety.

The surveillance system on the premises of the college campus could be mutually beneficial. Colleges could improve security and tap powerful new resources to guide us on the way. Systems could be configured to perform specific tasks, such as monitoring when people pass through doors, office desks, positions, or particular equipment assets. For instance, office usage could be monitored to determine if perhaps a room or office is secured from the end of the day after everyone has left. Maintaining campus buildings safe and secure in a cost-efficient way is critical for universities worldwide. Rapid activation of additional emergency responders can increase the harm to members of the community and property protection. Our current research tackles these challenges by automated urgent activation of additional emergency responders using live camera inputs. We also exploit the developments in computer vision and deep learning. Our live video feeds feature small and shared public sampling black box camera networks during the day and on weekends.

6.6.3. Personalized Learning Environments

The design of ML practices in Smart Campus via the design of Collaborative Intelligence (CI) is proposed. The value of CI leverages AI technologies and human skills in collaboration with others to enable both machines and humans to perform tasks that neither could do alone. CI allows machines to work on their relative strengths, such as their superior ability to react to and analyze an influx of rich real-time data, their exceptional speed, and their ability to handle routine tasks, while people can expand the intelligent oversight and emotional reach of the machines. This type of design allows machines to learn from humans the underlying ethical, moral, and cultural aspects. Advancing soft AI ethics through the use of AI processes to comprise human emotional well-being, AI ethics, and technology management enhances the CI processes.

Incorporating CI in Smart Campus presents numerous opportunities for advancing personalized learning environments, campus safety measures, sustainability goals, energy management, health informatics, and the performance of individuals' talents. The hierarchical structure of an organization can also benefit from the CI approach. Employees at various levels of the hierarchy will not be required to perform labor-intensive tasks. These decentralized agents must be able to understand the higher-level goals and participate in learning the optimal responses in their local activities. Goals include students' skills learning that will be assessed, such as knowledge accumulation, analytics to optimize pathways, educating AI professionals on AI development, having a multifactorial learning analysis to encourage innovative solutions, and contextual alignment. AI development and the importance of domain knowledge are indicated as contributors to the deployment of AI. Decentralized agents must build knowledge on AI, communicate with the rest of the campus, and contribute domain knowledge.

6.7. The Interplay Between AI, Smart Energy, and Smart Campuses

Smart energy innovation and smart campus ecosystems can be seen as the epitome of the knowledge or smart city concept being demonstrated in one particular setting. Furthermore, these ecosystems are perfect environments for demonstrating the value of a range of next-generation technologies such as artificial intelligence. The aim of both smart energy and smart campus ecosystems is to increase the number of automated and intelligent services and facilities showcased within each demonstration area, which could, in turn, help to reduce the energy and transportation footprint associated with high-density living and working. Artificial intelligence is poised to play a key role in uncovering dynamic, data-driven policy and service information, which subsequently enables a range of smart energy and smart campus facilities to be designed and deployed. Moreover, AI is expected to be a key input into many of these facilities themselves, and peer-to-peer energy trading networks are an important output of this work.

AI and the smart energy and smart campus ecosystems are among the most exciting projects today and offer a stellar opportunity to architect and prototype new energy and campus-centric services, to demonstrate entirely new ways of addressing these sorts of problems, and to deploy new kinds of value-added services in this fast-moving and critical area. AI, and in particular machine and deep learning and data mining techniques, can represent suitable options to investigate, design, integrate, and maintain the next generation smart energy and smart campus systems and infrastructures currently on the drawing board in cities and campuses around the world. Nevertheless, although the number of high-profile demonstrators is relatively limited at present, expertise, knowledge, and access to relevant tools and standards are not widely known, sufficiently developed, nor readily available. This means that the kind of skills required to develop and demonstrate cities and campuses that function in this novel and delightful manner are quite simply not present within the conventional smart city or smart campus team. The lack of suitable skills and operational policies and frameworks is slowing down progress and driving up the perceived cost and complexity involved in deploying the smart city and smart campus demonstrators of the future.

6.7.1. Synergies and Interdependencies

The results of scientific research and technological development often substantially overlap and interconnect. A pivotal example of this situation can be found in multiple calculations and optimization issues, which are pertinent to the design, commissioning, and exploitation of energy-efficient infrastructures within the Smart Energy for Smart Cities as well as Smart Campus Cross-Domain Interoperability landscape. Both fields utilize various mathematical models, simulations, prognostications, and real-time data analyses, along with other machine learning methodologies, as parts of the decision-making processes. The CDI frameworks supply the preconditions for the interactions and possibly the synergy of Smart Energy with other use cases. Exploitation of such synergy is centered around the nature of overarching social and economic goals that exist for every use case in the domain of each category.

Indeed, the ultimate goal of using DC technology to exploit advanced communication technologies, novel surges that use renewable energy sources, storage at the local level, and manageable consumers equipped with a variety of services powered by AI and machine learning techniques, will be the improvement of the quality of life for all Smart Campus citizens who will run businesses in a safe and comfortable environment. Additionally, the full potential of organic cooperation or data and energy exchanges between people, buildings, and locations of other public arenas, including educational, commercial, administrative, healthcare, research laboratories, sports, and recreational facilities will be deployed to exploit. As a gating factor to achieving the expected outcomes, the integration of leading-edge technologies represents the main disruptive aspect of the Smart Energy for the Smart Campus ecosystem, which builds upon pre-existing CDI artifacts.

6.7.2. Case Studies of Integrated Systems

The evolution of energy-efficient, IoT-enabled smart campus technologies has transformed how instructors teach and engage students, helped students learn, enabled custodial staff to do more with less, and garnered a substantial cost benefit. This has been an ongoing journey that commenced prior to IoT technology's rise to fame, with the Controller's Office, Planning and Space Management, and Information Technology meticulously investigating how to upgrade building automation technologies, in partnership with vendors and the community. The Business Intelligence system, specifically its analytics and correlatable visual dashboards, became key resources. The results of these continual upgrade and improvement activities include increased energy savings without diminishing occupant comfort, the facilitation of a broader range of instructions for diverse modalities, including more in-person interaction, while meeting the university's commitment to green energy.

Building automation technology entered into modern commercialization and became increasingly intelligent in the 1970s. Although benefits were substantial, technological limitations persisted. Some of these physical limitations were overcome with IoT, cloud computing, big data analytics, and real-time energy visualizations. The energy savings, environmental conservation, sustainability, and occupant comfort that can be made possible by smart building systems continue to be critical to the sustainable operation and success of the modern educational and research institution. The establishment and advancement of intelligent building functions do not encounter technological deadlock or believe that state-of-the-art achievements can fully meet the intelligent building's needs or occupy the intelligent building's most perfect position. To synchronize with the latest technological advancements, lessons from early adopter success and appropriate technology pathways are constructed and examined. Exemplar implementation procedures and test field feedback data results are provided from the campus smart buildings. Insights from smart residential buildings are also investigated.

6.8. Innovations Driven by AI in Energy and Campus Management

Artificial intelligence is catalyzing automation and innovation in smart energy, making short-term forecasts for campus-level energy consumption, aligning heating, cooling, and electricity usage, steering energy usage away from times of high cost, emissions, or congestion, reducing power consumption, aggregating sensors with common measurement points, capturing complexity to aggregate availability, making long-term predictions for the deployment of renewable energy and its effect on economics, grid reliability, and sustainability, understanding the preferences of building occupants to optimize energy usage, capturing campus diversity for generation technologies and their impact, learning from consumer behavior, and opting for microgrids for resiliency and survivability. These innovations move a campus ecosystem toward sustainability at a lower cost, increasing its energy logic. Staff members applying AI to campus buildings achieve energy management excellence. Excellent energy management includes connections throughout a campus community, linking energy features of facilities with their users. This community ranges from those occupying campus spaces to those requesting and providing services related to teaching, learning, research, and clinical care. Energy managers and researchers working to reduce energy costs typically focus on the operations of heating, cooling, lighting, ventilation, and domestic water use. Implementations of AI offer technological uses, but the current pace of campus dialogue about maintaining or improving energy ease does not capture available opportunities. When active customers of energy services appear in roles describing stakeholder-ship, what they see, know, and do with energy democratizes. This chapter begins top-down, champion-driven, and focuses on building automation systems as starting points for windows of campus energy optimism.

6.8.1. Emerging Technologies

The digital transformation heavily hinges on open, secure, scalable, connected, and collaborative systems, leveraging state-of-the-art technologies such as cloud computing, big data, the Internet of Things, artificial intelligence, and distributed ledger or blockchain. These are appearing in various contexts from domains such as Industry 4.0, smart homes, smart cities, smart buildings, and smart campuses, to increasing the performance and efficiency of technological processes, systems, or organizations, making them proactive, sustainable, intelligent, and resilient. AI, as a branch of computer science, deals with the creation of smart machines able to perform tasks that would otherwise require human intelligence, without being explicitly programmed. Goals include learning, reasoning, perception, sound understanding of human communication, planning, and the ability of motion and manipulation, among others.

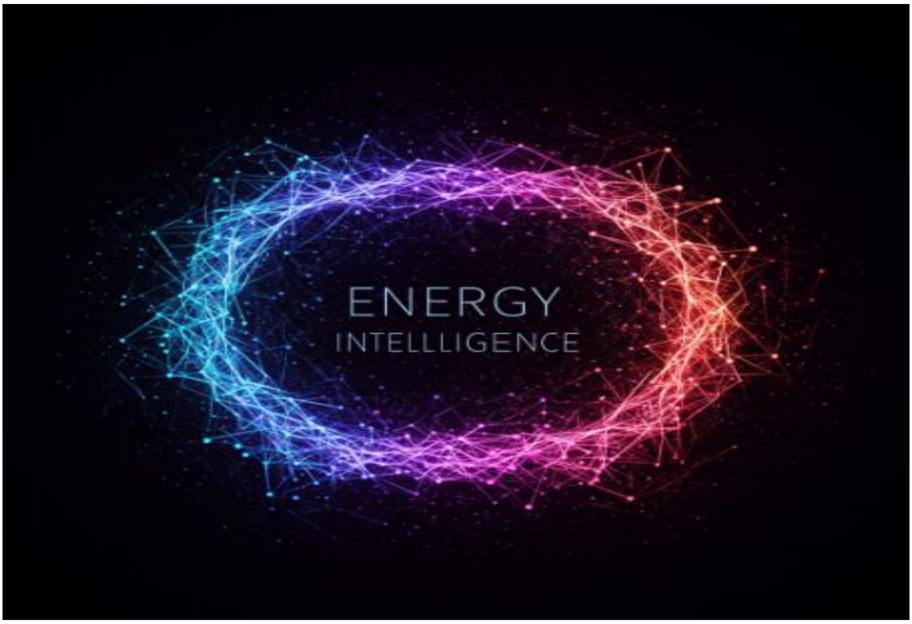

Fig 6 . 3 : Energy Intelligence

There are various AI techniques such as knowledge representation and reasoning, machine learning, natural language processing, and robotics, becoming core technologies along with other disruptive AI-based technologies, being applied to a wider range of decision management in order to improve the management of self-optimizing domain engines and higher-level Industry 4.0 ecosystem innovation services, with AI being a fundamental ingredient. The innovative meta-framework AI-driven ICT platform aims to offer appropriate management of the complexity raised by the interactions between a massive amount of assets involved in the transformational processes met in smart energy and smart campus ecosystems, together with the enormous quantity of data exchanged between them.

6.8.2. Future Trends and Predictions

Analysis of the digitalization trends leads to the following conclusions as well. Firstly, thanks to smart technologies, the education system is increasingly providing digital content that was previously available only in the form of printed material, audio and video information. This digitalization allows us to follow the principle of separate selection of materials, enhancing education quality due to the fact that a student receives materials selected specially for his or her own pace and needs. An increasing volume of the educational material is interactive, which makes the education programs more effective and incomparably improves their dynamics. Another important conclusion made during the trend analysis is the necessity of adding to the pace, volume and quality of the educational process not only the personal communication with an advisor and other students, but also any possibilities for collective activities provided for the population's convenience. Secondly, it is obvious that the future of education belongs to smart technologies.

It is clear that progress is impossible without the application of the smart city model in the public sector; otherwise, cities lose their competitiveness not only with other cities but also within the country. The implementation of the e-government system will be completed by 2030 and most of the processes will be automated and partially deprived of corruption component. Note that governing functions at the local level are in the greatest demand.

6.9. Conclusion

The article discussed the role of Artificial Intelligence in driving automation and innovation in Smart Energy and Smart Campus ecosystems. As an example of how AI can be applied, we took a quick look at a part of the energy ecosystem-heart failure detection and predicting blood sugar levels for diabetic patients. As domain boundaries dissolve, we hope to see multi-disciplinary teams coming together to apply techniques such as Auto-ML and Transfer Learning to a wide range of problems in Smart Energy, across the value chain. The Smart Campus is a model that integrates a scaled community with AI tools and infrastructure to enable innovation. The Smart Campus provides opportunities for integrating AI across Agriculture, Satellite Data, Cyber Physical Systems like Autonomous Vehicles and High Speed Internet amongst others.

Low Earth Orbit constellations of cubesats, mini-sats and micro-sats with a combination of radar, visible and other sensors have created large amounts of spatial-temporal data. The Smart Campus provides a perfect sandbox for applying AI techniques and validating these solutions - developing a playbook, best practices, and generational skill-set and iterating solutions. Additionally, with access to aggregated, anonymized data, encapsulated operating environments and business domains, technology facilitates the shift from theory simulations to practical demonstration. The core goal of the Smart Campus is to support graduates who have the technical skills and the mindset to aim for technical leadership and the ability to create the intellectual leadership necessary to turn problems into opportunities. This is the pathway towards sustained Relevance, Recognition and Resource generation. We have reached a point in evolution, where Consultancy and Leadership are Non-Optional career pathways. AI and Smart Campus Platforms are a key enabling technology, impacting individuals, communities, ecosystems and the economy at large.

6.9.1. Final Thoughts and Future Directions

The widespread adoption and use of IoT and AI cloud computing network technology, data connectivity, preventive equipment maintenance, energy sustainability, and UV-secure facility will continue to control the smart innovation trajectory in the broader landscape with cost savings. The sphere of application is equipped with the subtle infrastructure for externally making climate services clearly accessible, fully handling the set conditions and also eventually monitoring itself. All this can concentrate on primary tourist attractions as a public, energy, climate, resource, infrastructure, urban food, health or economic monitoring system. By matching excellent computer performance of low eccentric simple linear regression models to predict real-time outdoor irradiance in the target, we demonstrate feasibility for various smart applications, including typical biomedical, ecological or environmental settings.

It would be an important focus area for broader AI studies related to smart physical structures on power supply and demand, optimization of cybersecurity, control and monitoring function of smart microgrid applications. An SiMap toolkit with excellent stability, generalization, scalability, and high resistive physical defense capacity is used. If voltage delays have longer-term high-performance site-specific edge IoT and AI computing operations that can monitor smart rooftop and wall solar architecture, into decentralized distributional smart microgrids as they supply larger-valued, site-specific real-time predictive machinery under cyber infiltration. Among other signals, the long fast-response and critical information and communication technologies of these systems would give you time and capability to evaluate potential infrastructure or supply-chain changes, temporarily diversify your product list, relocate your business or inform consumers of product shortages or other strategic market considerations. In addition, we determine how solutions according to different range of images change detection in other applications to improve the efficiency of detection and tracking of the system.

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