

RESEARCH ARTICLE

Artificial Intelligent Intervention to Urban Building Renewable Energy Modeling for Robust Energy **Flexible Communities**

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Abstract

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Key words:-

Positive energy District, Open Modelica, Artificial Intelligence Algorithms, Urban Building Renewable Energy Modeling, Internet-of-things, Bio-Plants, Microgrids

This research coveys a comparative analysis between Urban Building energy model (UBEM) generated by scholar, researchers, and professional in academia and industry while highlighting the reliable main components to manifest a successful and reliable UBEM technologies. Nevertheless, it consolidates distributed generation on building blocks rather than a whole district relying on renewable energy sources. It guides engineers through energy system model simulation on Openmodelica platform to feed green sustained communities. Moreover, energy use-pattern is mapped and analyzed by internet of things (IOT) technologies to fine-tune energy uses and refine use-pattern. Demonstrating artificial Intelligence (AI) algorithmto predict energy consumption can reflect on the amount of energy required for storage to cover energy needs. AI shapes a robust positive energy district (PED) through storinggenerated renewable solar or bio-energy to cover predicted energy use-pattern.Distributed -powerplant stations capacity to cover clusters using AI in predicting energy consumption consolidates on-site energy generation recommended by multiple International rating systems. AI-based Energy management plan guide engineers and planners to design distributed-power-plants of energy generation capacity lies between the actual energy need and a predicted scenario.

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Introduction:-

Rapid urbanization stabilizes an exponential increase inenergy use.De-carbonized energy resources promote city expansion in a sustainable development envelope. LEED -ND has addressed 'renewable energy production' with 3 credits under 'Green infrastructure and buildings' (Council, 2016).

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Nevertheless, providing district with onsite energy generation within a smart microgrid. SST, solid state transformers have enabled smart grid application through opposite current usability on the main grid.

Another technology on stream to manifest sustainable development is distributed generation. The shift from one central mega-station providing a whole city, it empowers small districts with multiple central mini-stations. Such concept can facilitate the consolidation of renewable energy on the district level. Allocating distributed stations that runs renewable energy resources manifest decarbonized energy powering clusters based on each station capacity.

Utilizing Solar Power along with Bio-gas generated from domestic use is the best strategy for energy efficient districts. Residential buildings contribute with a generous amount of bio-waste which can be feedstock to bio-power stations.

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Simultaneously, refining energy-use patterns on the district level is another stream to work on towards energy efficient district. Monitoring residents' use pattern and providing them with a threshold to meet can be easily implements using internet of things, IOT, technology.

Problem / Motivation:

Urban sprawl is escalating at the same time energy and water issues have not yet been resolved. City flow of inputs and outputs balance in terms of city metabolism aims at engaging feasible and quick solutions to refine resources use-pattern and fulfill city equilibrium. In the light of metabolic neighborhoods, refining use-pattern of inputs and outputs is priority. Nevertheless, applicable technologies consolidate planners' targets.

Energy is on the top of inflow and outflow of a city metabolic scenario. Energy efficiency has triggered mathematical models, simulation tools and designers to elaborate passive design strategies and mitigate energy consumption in micro-scale. Moreover, envisioning energy management on the urban scale incorporates to address energy issues. This research contempt to propose a framework to demonstrate energy efficient districts while adopting AI algorithm for energy use-pattern prediction.

Manifesting PED with renewable energy resources stored to cover predicted energy consumption is a robust industry application of AI algorithms including deep learning; Artificial Neural network (ANN). All power-plants are designed to support on-site renewable energy generation of current consumption with no positive- Energy scenario. In order to manifest PED, power plants must be designed to meet predicted energy use with full potential capacity.

Another energy management plan to use-pattern refinement shall take place simultaneously.

Methodology:-

This research methodology revolves around three main aspects where energy efficient district stabilizes Including Distributed stational technology, renewable power-plants, Internet of Things and energy Use-pattern Refinement, AI Algorithms potentials in prediction as yielded in figure 1.



Figure 1:- Positive Energy District Using Artificial Intelligence.

Three main pillars; Energy monitoring using IOT, Renewable energy power-plants (bio-energy or PV farms) Each sector in the proposed methodology will be illustrated and analyzed as follow:

Distributed stations technology:

In the realm of green neighborhood certification, smart grid was a proposed energy-management on the urban scale that aims at supporting two-reversed-direction on the main grid. On-site energy generation demonstration interprets smart grid implementation to enable two-source electricity. Hereafter, distributed stations technology is revealed to empower clusters using clean resources as illustrated in figure 2.

Distributed technology sometimes referred to as decentralized where blocks empowerments sourced to multiple local stations instead of a central one. This energy management scenario facilitates a tailored technology to each neighborhood based on its use-pattern.

Distributed generation may serve a single structure, such as a home or business, or it may be part of a micro grid (a smaller grid that is also tied into the larger electricity delivery system), such as at a major industrial facility, a military base, or a large college campus. (J W Kolar, 2012)



Figure 2:- Distributed generation Infrastructure (Emi MinghuiGui, 2017).

Renewable Energy Plants: Bio-power plants:

Renewable energy resources are various including solar energy, hydropower, biogas, geothermal, and wind power. PV cells are the most reliable and easy to implement on building blocks on unit-scale. However, cluster empowerment requires mor robust energy source. Biogas stations can be easily populated and located within a neighborhood providing its blocks with clean and decarbonized energy. Food waste (FW) represents the feed stock to disturbed bio-power stations.

Canada had the highest FW generation rate with 0.5 kg FW/capita/day(Massow, 2011), followed by the United States with 0.3 kg FW/capita/day (110 kg FW/capita/year)(Venkat, 2011). The highest generation of FW in European countries has been noted in England with a total FW amount of 14.257 million tons annually. Germany generates about 12.258 million tons/year (Preparation study on food waste across EU 27, 2010). Consequently, FW can be a primary source of decarbonized energy easily to be implemented on neighborhood scale while manifesting distributed stations technology.

These stations can be easily simulated on Open modelica platform. Bio-power plants can generate heat and electricity needed on the district level. Combined heat and power stations are recommended to support renewable energy-based districts as illustrated in figure 3.



Figure 3a. Schematic of Brayton cycle with recuperator using three turbines combination, b. Schematic view modelling for the proposed library in Modelica.(Zohuri B., 2015)

Energy use-pattern Refinement:

Identifying energy use-pattern on the urban scale requires integrative approach amongst specialist and stakeholders. European Union has endeavored multi-disciplinary program to address energy-efficient districts.

Realtime-Monitoring of energy consumptions and identifying excessive use-pattern is through implementing IOT, Internet of things, technology to induce pragmatic and prompt intervention. Handling energy efficient operation's needs.

Refining residents' use-pattern using IOT technology is another dimension to be undertaken that monitors energy use and migrate it to cloud smart grid as shown in figure 4. Incorporating layers in digitized data while connecting to power stations to orient energy traffic. IOT nodes are allocated at each building block to monitor energy use-pattern while recommending a tunned one.



Figure 4a. Model scenario proposed. Different sources of renewable energy, buildings, and housing are organized in a management layer (smart grid intranet). IoT nodes, smart grid layer, electric distribution control, and cloud services are the items shown b. Model layer architecture with the main elements and their relationship. There are two node types: edge and fog. Each facility (building, solar generation, etc.) can have its own local network. All the nodes and all local networks are related to the energy (smart grid) and cloud management layers. (Francisco Javier Ferrández-Pastor, 2019)

Energy meters readings using IOT-based devices is an indicator to energy consumption to guide the required generated capacity. Energy management plan is to be implemented following energy capacity interval of the total actual consumption and the predicted scenario to be illustrated later in the following section. Moreover, A refinement plan to meet the international or national rating systems for green buildings and communities' benchmarks in energy consumption.

Artificial Intelligence Algorithms for Energy Prediction:

Mathematical models for performance optimization have witnessed a great shift both in academia and practice. Artificial Intelligence algorithms have demonstrated quite a success and promising results in multiple application in predicted data and design generations. These algorithmic optimization interventions can easily enhance energy storage using renewable resources and define a range for energy consumption to bounce between.

Further studies using multiple AI algorithms to predict energy consumption has taken place as shown in table 1In this analysis support vector machines (SVM), artificial neural networks are mainly used. In the usage of SVM and ANN, a data set obtained from the smart data acquisition device was used for the training of these algorithms(V.L. Abeykoon a, 2016)

In unsupervised learning the output group is decided by the algorithm itself. The only input to the algorithm is a training data set and it clusters the inputs by itself. In this K-Means, Mean-Shift and Silhouette algorithms were used

to test and classify data. The K-Means algorithm provides a higher accurate result than other two algorithms. (V.L. Abeykoon a, 2016). Data Clustering and Classification has followed a supervised and unsupervised typology in which more than one algorithm has been tested to predict datasets.

Туре	Classifier	Accuracy (%)	Execution (s)
Supervised	SVM	97	0.010
Supervised	ANN	96	13.000
Unsupervised	Mean Shift	94	0.013
Unsupervised	Silhouette	98	0.012
Unsupervised	K-Means	98	0.150

Table 1:- Data	Acquisition	and Performance	(V.L. Abe	vkoon a.	2016).
			(,	

This analytical and empirical study emphasize the accuracy and reliability of neural network (ANN) in data prediction based on data acquisition from meters or devices. This should orient our research to focus on neural ANN intervention into simulation results and predict energy consumption or future use-pattern to manifest a Prediction-based power-plants.

Open Modelica: Neural Network Simulation Platform

OPENMODELICA is an open-source Modelica-based modeling and simulation environment intended for industrial and academic usage.(Association, 2021). This platform supports multiple libraries that includes AI algorithms like ANN to provide optimization to energy system model simulations. ANN library is available for Open Modelica users to experiment its potential in system simulation results prediction for future patterns.

Results:-

Modelica is one of the most reliable platforms for physical and mathematical model simulation. However, there are many other computational platforms to manifest efficient energy districts. Many institutions and entities have been investigating and generating multiple platforms to demonstrates energy efficiency and refinement on the urban scale.

Urban Energy-efficient Platforms (Comparative Analysis):

Timegeo, OptEEmAL, and CityBES, have adoptedurbanbuildingenergy models (UBEM) to monitor occupancy, energy consumption, whileCITyFiEDhas addressed building retrofitting. CESAR by KTH has utilized IFT files from Revit and illustrated urban scale heat map using 3D geo data. Energy plus as energy simulation engine has been adopted in building retrofitting in CESAR, CityBES as shown in table 1. On the other hand, CITyFiED has focused more on building retrofit using bioclimatic designs.

1.TimeGeo	I. MIT,	III. CARLO	Boston	Mobile-Based Application	Mobile phone
	II. MASSACH	s Cerezo	metropolit		based occupancy
	USETTS INSTITUTE	DAVILA,	an area,		estimates are
	OF TECHNOLOGY	IV. CHRIS	USA		integrated with a
		TOPHER			state-of-the-art
		REINHART			urban building
					energy model to
					understand their
					impact on energy
					use
					predictions.(Edwar
					d Barbour, 2019)
2.OptEEm	V. UCL,	Miguel Á.	Trento,	Cloud-Based Platform for	Optimized Energy
AL	VI. UNIVERSIT	García-	Italy	IFC file enrichment	Efficient Design
	Y COLLEGE	Fuentes,			Platform able to
	London,	Susana			design energy

Table 2:- Platforms and research application to address energy efficient districts.

	VII. CARTIF Technology Centre	Martín		Imput Imput <td< th=""><th>efficient retrofitting projects that are based on different energy conservation measures to improve the behavior of a district. (Miguel Á. García-Fuentes, 2020)</th></td<>	efficient retrofitting projects that are based on different energy conservation measures to improve the behavior of a district. (Miguel Á. García-Fuentes, 2020)
3.CityBES	VIII. LBNL,LA WRENCE BERKELEY NATIONAL LABORATORY	Tianzhen Hong, Wanni Zhang, Han Li, Xuan Luo, Kaiyu Sun, Mary Ann Piette Yixing Chen, Yujie Xu, Daryn Lee, Bill Zhai	San Francisco, USA	web-based data and computing platform	focusing on energy modeling and analysis of a city's building stock to support district or city-scale refficiency programs. CityBES uses an international open data standard, CityGML, to represent and exchange 3D city models.(Hong, 2016)
4.CITyFiE D	IX. FUNDACIÓ N CARTIF, X. SPAIN	Ali VasalloBelver	Laguna de Duero- Valladolid (Spain), Soma (Turkey) and Lund (Sweden)	Standalone	enhance the energy efficiency of the city districtthroughbuil ding retrofitting, district heating and energy systems upgrades, smart grids, integration of renewable energy sources and monitoring platforms. (Thompson, KEY INGREDIENTS FOR A SMART URBAN DISTRICT, 2019)
5. CESAR	XI. ETH Zurich, XII. Switzerl AND	Jan Carmeliet	Zurich, Switzerlan d	Standalone	better knowledge of the current building energy profiles and to address future energy saving potentials and CO2 emission reductions by retrofitting strategies(Carmelie

		t, 2016)

These platforms monitor energy consumption and then comparing it to a benchmark to recommend a tunned energy use-pattern withing energy efficient scenario. Modeling on a GIS or urban microscale tool interconnect use-pattern. Building design retrofits encompasses passive and bioclimatic strategies to mitigate energy loads. Nevertheless, referring to different building types benchmark requires a computational mathematical model to identify percent of energy reduction as demonstrated in figure 5.



Figure 5:- CityBES interface (Yixing Chen, 2017).

Conclusions:-

Urban Micro-scale energy efficiency relies on performing advanced technologies which can be summarized as follows:

- 1. Distributed Stations manifesting microgrids
- 2. Bio-power plants as a primary renewable energy source
- 3. IOT for Energy Use-pattern monitoring and consequently setting tunning scenario.
- 4. AI Algorithms for Energy consumption Prediction

Urban-scale energy-efficient studies incorporate multi-layer process. It requires multi-disciplinary origin teams to explore these layers. Some researchers have addressed it with a top-bottom approach working on clusters utilizing 3D GIS data, while others have developed platforms applying bottom-up focusing more on buildings retrofitting like Citified by the EU fund.

Organizing and setting inter-operable files for data stream is substantial. Evidence-based research methodology through investigating implemented examples in addition with simulation-based experimentations consolidates a reliable platform as delineated in figure 6.

AI algorithms intervention in manifesting PED based on renewable power-plants encapsulate the plants' capacity between the actual energy consumption and a reliable predicted scenario through AI-based energy management Plan.



Figure 6:- Applicable technologies manifested to consolidate energy efficient Districts (Author).

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