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Identifying the Need for an Energy Urban Planning Role

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Abstract— Approaches to reducing energy consumption in multi-family residential buildings can benefit from being more intentionally integrated with non-energy urban planning efforts. Despite the large volume of energy data available, some of the data that would be useful to plan more sustainable urban development or retrofit existing building stocks are incomplete or not integrated with data that is being used for decision-making. This article identifies data issues that limit the effectiveness of energy efficiency planning efforts and proposes solutions to surmount these challenges. Further, the role of an Energy Urban Planner (EUP) is proposed to resolve the identified gaps with consideration for more thoughtful and integrated planning approach. Lastly, the article discusses the potential implications of an EUP role for both urban planning more broadly and specific approaches to reduce energy consumption. The methodology combines qualitative research with key energy efficiency decision-makers in three municipalities and a data quality and spatial analysis case study of Chicago Energy Benchmarking data. The qualitative research consisted of interviews that were conducted to explore how municipalities and NGOs plan efforts to reduce energy consumption in multi-unit residential buildings. In the case study, 2017 energy benchmarking data (reported in 2018) are analyzed for data quality issues and patterns that emerge from geographic and urban form variables. The qualitative findings are combined with the results from the Chicago case study to identify the need for more integrated urban planning. The objective is to highlight data that can be intentionally integrated to bolster energy efficiency efforts across professions.

Keywords— energy consumption, energy use intensity, data quality, energy planning.

I. INTRODUCTION

Nowadays there is a huge amount of available data. On the one hand, energy companies collect many different variables from numerous sensors, customer energy bills, having both generalized data and interval data for specific locations and periods of time. On the other hand, urban planners and municipalities have access and proficiency to work with urban data, including variables from census, demographics, and the built environment. Even though urban planners are historically not trained very well to work with big and complex data [1], the need for work and making policies based on the complex data-driven outcomes is increasing. The problem is that often these two sources of data overlap poorly or do not overlap or interact with each other at all.

Energy benchmarking data is an example of a dataset that is publicly available. This data is not comprehensive. In the City of Chicago, it targets only a specific subset of energy consumers (large buildings over 50,000 sq ft), and it includes only a few variables. Further, the data is self-reported which might cause inaccuracies, and the geographic distribution of buildings is not randomly distributed. Other than access to this data, there is a lack of more detailed and high-resolution energy demand data [2-4]. Sometimes utilities share or sell partially aggregated data to third parties, but access to this type of data is limited due to the absence of public knowledge about it [5].

Many studies have used data analytics as a powerful way to identify patterns and model various aspects within the urban infrastructure context [6,7]. The method used in this article can help to further decision-making on the energy efficiency implications of planning. Urban planners' role in the context of energy efficiency is not limited by well-known processes such as managing energy efficiency programs, strategies, and creating large energy plans. Usually, these planning processes, which are typically organized and supervised by municipalities, only provide a theoretical framework for the whole city or region that cannot be adopted straightforwardly and easily on a local scale [8].

Working with the existing buildings and improving the existing conditions (e.g. [9]) is only one type of effort. Another important role is to participate in the energy-driven design of buildings and districts on the neighborhood scale and implement principles that will not undermine energy efficiency efforts. Urban planners who are focused on the energy component of design are responsible for the development of plans for the new construction or demolishing/remodeling projects which are staying in line with energy efficiency goals and better energy performance overall.

Urban planners in this case need to have explicit and detailed information about the specific area of the work and have enough knowledge based on processed data from other case studies and projects. Thus, planners and policymakers should be equipped with all necessary tools that are required to propose computationally optimized solutions and design which will be likely more efficient than those based on the designer's intuition only [10]. Simulation-based modeling is an efficient way to get these results [11,12]. During the interrelated modeling and design process, many components of the successful district might be achieved, such as the optimal urban form, population, and built environment density, architectural solutions, and technological decisions of energy infrastructure.

For example, an urban form which is one of the important variables associated with energy consumption [13-16] is not collected and is not available in any energy-related datasets, whereas thoughtfully and properly selected components of the urban form can reduce energy demand. The metrics in energy benchmarking data can include both characteristics of the building (e.g. height, materials of the construction, HVAC systems installed, type of energy source – gas/electricity) and the built environment of the surroundings (e.g. Floor Area Ratio, connection to the neighboring buildings, population and built density of the district). Ready access to this data enable planners and energy efficiency decision-makers will be able to make informed decisions even within the limited time or limited staff capacity.

Timely updates and verification of data accuracy are two important characteristics of building reliability and trust in energy benchmarking data [17]. Unfortunately, there is not enough capacity to verify the accuracy of data that has been reported voluntarily and the data has not been updated in a timely manner. As of this publication, the most recent available data is from 2017 which is more than three years old. Taking into account a global rich data environment and speed of technologies change, this data is becoming unreliable as a decision-making tool. Publicly available, accurate, timely prepared, and a plurality of energy data variables will help energy urban planners to be more involved in the energy-driven design and development processes. Accessible, complete, and accurate data can facilitate the development of more sustainable and energy efficient development projects.

II. Methodology

In this study, we combined the qualitative research of key decision-makers in energy efficiency planning and quantitative analysis of a case study using a sample data from City of Chicago Energy Benchmarking Data. The qualitative research consisted of interviews that were conducted to explore how municipalities and non-governmental organizations (NGOs) plan efforts to reduce energy consumption in multi-unit residential buildings. In the case study, 2017 energy benchmarking data are analyzed for evaluating the potential patterns that emerge from geographic and urban form variables. The qualitative findings are combined with the results from the Chicago urban form analysis to identify the need for more integrated urban planning.

A. Built Form Analysis

Primary and secondary data were used to explore the relationship between energy consumption patterns and the built forms characterizing multi-unit residential buildings. A random sample size of 400 was selected from a total population of 1,391 multifamily buildings. For each building, data on the following variables were collected and analyzed.

Secondary data derived from the 2017 Chicago Building Energy Use Benchmarking data [18] included the following variables: gross floor area and weather-normalized energy use intensity (EUI). Given that the Chicago benchmarking ordinance does require the collection of data on urban form, primary data were collected through observing each of the 400 selected buildings and recording two variables:

- Number of floors
- Attachment to other buildings

This study explores the correlation between urban form variables and Weather Normalized Source Energy Use Intensity (EUI). It is calculated as the source EUI per gross square foot (kBtu/ft2) of the property, normalized for weather. Weather normalization facilitates comparison between buildings in different parts of the country and corrects for year-to-year differences in weather [19].

B. Interviews

Qualitative research was employed to gather data on how key decision-makers perceived the need for energy-related urban planning, designed approaches to reduce energy consumption, and assessed the data that supported their approaches. The study interviewed 24 decision-makers, including: municipal Energy and Sustainability Managers, energy efficiency-related NGOs, and multi-unit residential building owners and management groups. The cities included Cleveland, Ohio, Detroit and Grand Rapids, Michigan, and were selected based on the following characteristics:

- Municipal budget and capacity challenges.
- Midwestern cities with a history of industrial decline
- Legacy multi-unit residential building stocks in need of repair.
- NGOs that use both sectoral and spatial approaches encouraging building energy retrofits.

The NGOs and building ownership groups operate in more cities than the three listed, including Chicago, Illinois. Municipal employees of the City of Chicago were not included among the interviewees due to NGOs using a spatial approach not operating in the city. Interviewees were selected based on their role as key decision-makers in energy efficiency retrofits or programs supporting the reduction of energy consumption among multi-unit residential buildings.

The interview protocol consisted of a semi-structured questionnaire. Open-ended questions were used to gather rich, qualitative data about the interviewees' perspectives. The objective was to allow the space for interviewees to provide definitions and assign value based in their respective positions.

III. Results

A. Building-level Urban Form

Energy issues are firmly connected with the focus of contemporary urban planning and the decision-making process. However, the processes of urban planning and city design do not function taking into account energy needs. Different challenges are coming from the point of harmonization and overlapping scientific, political and administrative complexities [20]. Moreover, in Chicago Energy benchmarking data, there are no variables that might be considered as an important component of the urban forms. Only combining the building footprint data and Energy benchmarking data might give a reasonable basement for the analysis.

To test how certain characteristics of urban form might impact the energy consumption, we decided to have a look on built form, which is one of the main complex variables which refers to the shape, configuration, and function of the building and its relation to other buildings and a street landscape. To examine the hypothesis that even two characteristics of built forms that are not currently present in the Energy Benchmarking dataset can be used as good predictors of the energy consumption, we include two dimensions of the building characteristics: building height and relation to neighboring buildings. We are looking at two dimensions of the buildings: if the height of the building is low, medium or high, and whether the building is attached to another or detached [21]. We took a random sample of 400 multifamily residential buildings from the dataset to process our analysis.

Based on several studies, it is generally accepted that detached houses are usually less energy efficient than attached houses of the same size due to increased exposed surface area [22,23]. This happens because attached buildings share one (or more) walls with neighboring buildings. Therefore, the total surface area that is exposed to outside conditions is decreasing. This helps to minimize potential losses because of the isolation, materials and other characteristics of the walls. To find the correlations we apply the linear regression models to determine the correlations between dependent (Weather Normalized Source Energy Use Intensity) and independent variable (Built Form with two parameters).

As we can see from the data analysis Fig. 1, the best energy performance is shown by low-rise attached buildings that have a lower median for their data. This means that this built form (followed by low-rise detached buildings) are more efficient in terms of energy consumption. At the same time, buildings with high-rise built form (both detached and attached) have the highest medians and it shows a positive correlation between variables.

A good case of this type of built form is the case of the development of the Barcelona compact city model [24]. In the case study of urban form and energy consumption in Barcelona, it was found that at a neighborhood level, the most effective remediation targets are the medium and higher density urban areas [25]. In terms of Barcelona, such a density is achieved mostly by compact blocks with attached buildings of 3-6 floors (100 and 160 dwellings/ha with an average occupation of 2.5 people per household). It is difficult to achieve energy self-sufficiency for areas with densities that are above or below these values [24].

As it was previously discussed, the defined parameter of urban form (built form in our case) which is not currently presented in Chicago Energy Benchmarking data and not collected by municipalities is the important variable to predict Energy Use Intensity and, therefore, possible energy strategies in general. As this variable that includes only two simple characteristics of the individual buildings might become a good predictor of energy use, adjusting the process of data collection for energy-based urban planning might be helpful.

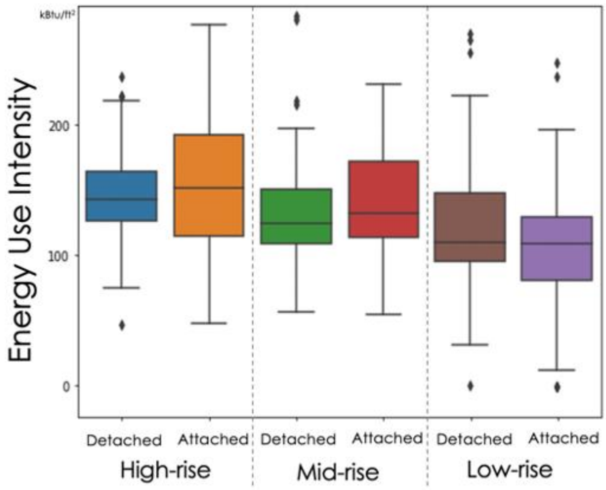

Fig. 1. Distribution of energy use intensity by urban forms.

These adjusted data will help to organize many actions including the implementation of passive design strategies, constructing low- or "zero-" energy buildings, and the efficiency improvement and retrofit of the existing buildings that are equally important to the neighborhood-level improvements since building siting, design, overall community layout are important factors in energy consumption [26]. Therefore, we believe that collecting this type of data from homeowners should be integrated with issues regarding energy use and will help to create better recommendations based on the results of data analysis.

B. Data Quality Issues

Energy-related urban planning requires data that can be trusted to accurately inform decisions. Energy benchmarking data includes errors due to the data being self-reported by building owners and the lack of municipal capacity to verify reported data. Further, urban planning decisions often require combining data layers, such as the energy benchmarking data with the building footprint layer, and demographic data from the US Census.

Fig. 2 visualizes energy and building footprint data in the Streeterville area of Chicago) to demonstrate data quality issues. First, cyan highlights show building footprints that are labeled as having more than one unit. Red dots identify the location of multifamily buildings reporting energy benchmarking data. With a quick overview, one can see that not all multifamily buildings are designated as such in the building footprint layer (all red dots would be in cyan building footprints). Second, some red dots are located outside of buildings, in the middle of streets. Therefore, an urban planner would need to clean this data, reassign the red dots to adjacent buildings (assuming the locations are only marginally off) before using this data to make decisions. Many municipalities are already stretched for staff capacity, which could make the additional time a significant barrier to using the data.

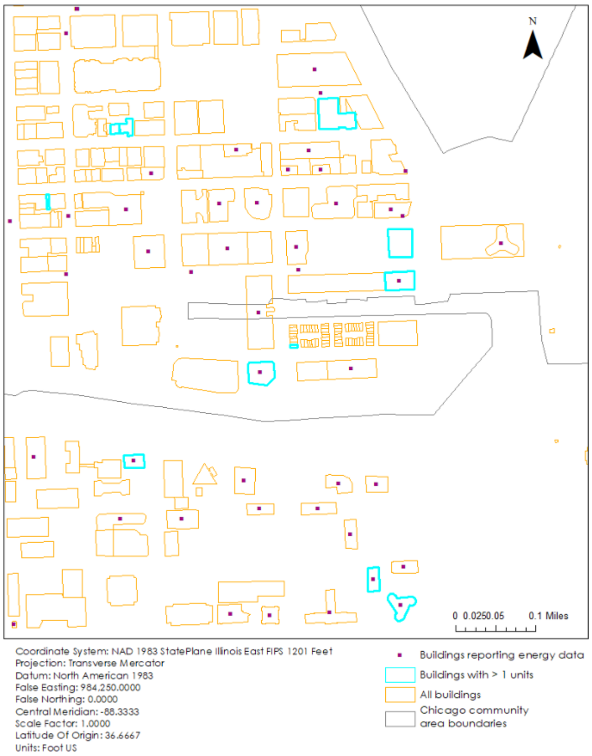

Fig. 2. Data quality and compatibility errors.

In terms of quality of the energy data, as we take a look at the reported accuracy of the studies that leveraged machine learning techniques to model the buildings' operational energy use in the City of Chicago [27,28] the maximum R-Squared achieved is about 0.7 which needs substantial improvement.

In order to improve the quality of the data for modeling and decision-making purposes, one limitation is that only small portion of the City's buildings are covered in the benchmarking dataset. In fact, in the 2017 dataset, the total number of buildings that are covered by the benchmarking ordinance are less than 1% of Chicago's buildings, and they account for 20% of total energy used by all buildings.

Another aspect is that an effective dataset should include the general building information in conjunction with the detailed building component data in urban scale. In the 2017 City of Chicago building energy benchmarking dataset the general information like building energy use, building age, gross floor area, etc. are available. But, the detailed building component and energy data (e.g. buildings' insulation material, windows type, geometry and shape, external shading devices, HVAC systems, etc.) are mostly unavailable in urban or neighborhood scale around the country.

C. Interviews with Eenergy Efficiency Decision-makers

Municipal Energy and Sustainability Managers often have limited information with which to assess their city's building stocks and make decisions on the most effective approaches to incentivize energy efficiency among building owners. Some limitations arise from challenges obtaining energy data from utilities; other limitations are due to data quality and inadequate data feedback between energy efficiency retrofit investments by building owners, recorded building performance measures, and updated databases accessible by municipal employees. Energy benchmarking ordinances provide a structure to improve information feedback on energy consumption but are limited to buildings with a minimal square footage (defined by each ordinance) and municipalities often lack the capacity to verify the accuracy of data reported [29].

Of the data that is reported, there are often inconsistencies with other relevant planning-related data, which makes integrating the data for larger urban planning more difficult. Further, municipal approaches to working with building owners to improve building energy efficiency are commonly parsed by sector (i.e. commercial, industrial, municipal, residential). This parsing is for good reason given the specificities of each building type, but it requires both the capacity and targeted strategies that would be effective in each sector. These are a few of the issues that highlight a gap between approaches to energy efficiency and the capacity to assess their performance. This gap represents a need for integrating approaches to energy efficiency with urban planning on a municipal and regional level.

While a city reports data on the energy efficiency of its building stocks to mark progress towards its sustainability goals, the ways in which energy efficiency approaches are implemented and the integrity of supporting data are often much more fragmented than they initially appear. Municipal approaches to reduce energy consumption among multi-unit residential buildings are often driven by the desire to reduce municipal costs and make progress towards sustainability goals, which can be defined internally or by regional organizations. The implementation is almost always carried out in collaboration with NGOs.

Utility companies, on the other hand, are mandated by their respective states to spend the money they earn through a fee to customers on energy efficiency programs. They are also internally driven to increase service reliability by reducing the amount of time energy demand exceeds peak capacity, requiring more expensive and polluting energy plants to come online and supply the difference. Here as well, NGOs are instrumental in implementing utility programs.

A key finding from the interviews was the municipalities and utility companies are largely siloed in implementing their own programs. NGOs serve as a mediator, helping building owners choose between the many incentive programs. The municipalities interviewed frequently work with NGOs to accomplish many of the tasks that require more staff capacity or resources than they have allocated. As indicated in Table I, the interviews revealed the different types of contributions that NGOs perform with municipalities and utilities.

TABLE I. MUNICIPAL AIMS AND NGO CONTRIBUTIONS TO HELP ACHIEVE THOSE AIMS

Municipal aims	NGO contributions
• Establish and agree to energy reduction targets • Assess energy efficiency of existing building stocks • Align planning and policy to achieve targets • Assign capacity and resources to implement and enforce means, (such as energy benchmarking ordinances) • Fund and inform residents of programs to help them invest in energy efficiency upgrades • Report energy efficiency gains and progress towards targets • Assess progress towards targets	• Liaise between municipalities, utilities, building owners, and tenants • Provide capacity and resources to conduct outreach with building owners and tenants • Promote public- and utility-based incentives to increase compliance and amplify voluntary participation • Provide an additional social infrastructure networks across which energy-related information can be shared • Collect participant feedback and generate energy-related data • Assess program effectiveness and assist municipalities with assessing progress towards targets

IV. DISCUSSION AND CONCLUSION

The findings reported from the spatial data analysis, and urban forms studies reveal the gaps in both data and planning that create difficulties for the ability of municipalities to effectively plan a reduction of energy consumption among multi-unit residential buildings. These difficulties become more visible as energy efficiency approaches shift their focus to the more challenging building stocks and building owners who did not respond to conventional approaches. This article highlighted difficulties in the following areas:

- There are parallel and often disconnected approaches to reducing energy consumption.
- Conventional approaches may not be fully effective with some types of building owners.
- Lack of data and coordination makes it difficult to assess the existing conditions of multi-unit residential building stocks.
- Data on relevant variables that influence energy consumption are not being collected and analyzed.
- Lack of complete and accurate data makes data-informed energy planning difficult.

The findings of the various methods used in this study demonstrate the impact of data challenges upon energy and urban planning. The lack of integration between energy planning and urban planning can lead to mixed results where development decisions can add energy consumption to a region, undermining the achievements in energy efficiency in other areas. The object of both energy and urban planning overlap in a common urban space, which is significant given the key role of cities in achieving broader energy targets. Thus, the complex interconnections between energy and urban planning require more intentional integration and coordination. Future research will include the analysis of datasets from other municipalities with different existing conditions and approaches to energy and urban planning.

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