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The Contribution of Energy-Optimized Urban Planning to Efficient Resource Use–A Case Study on Residential Settlement Development in Dhaka City, Bangladesh

Sujit Kumar Sikder [1,*], Francis Eanes [2], Henok Birhanu Asmelash [3], Shiba Kar [4] and Theo Koetter [1]

1 Department of Urban Planning and Land Management, Institute of Geodesy and Geo-information, University of Bonn, Nußalle 1, Bonn 44147, Germany; koetter@uni-bonn.de
2 Nelson Institute for Environmental Studies, University of Wisconsin-Madison, WI 53706, USA; feanes@wisc.edu
3 Department of Law, Bocconi University, Milan 20100, Italy; henok.asmelash@phd.unibocconi.it
4 Center for Land Use Education, University of Wisconsin-Stevens Point, WI 53706, USA; shiba.kar@uwsp.edu
* Correspondence: sujit.sikder@uni-bonn.de; Tel.: +49-228-73-9733; Fax: +49-228-73-3708

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Abstract: This study examines and explores the contribution of an energy-optimized urban planning approach to efficient resource use in the context of Dhaka city, Bangladesh. A conceptual energy optimization model called the "EnUp" model has been developed and tested for feasibility and adaptation strategies to improve urban energy use in residential settlements. This study is based on a system analysis and grounded theory approach that involved field methods including key informant (KI) interviews and collection of data and information from local urban planning offices and other secondary sources. Results show that the adoption of an energy-optimized planning approach is possible and necessary in Dhaka city. The "EnUp" model can be applied in new urban settlement planning and retrofitting existing urban settlements. Ensuring various stakeholders' participation, technical inputs, and adaptability could make this innovative model and approach replicable in many other cities in the world. The study facilitates a better documentation and visualization for comprehensive urban planning and energy planning process in developing countries, while providing useful insights to policy makers, planners, developers, and interested urban stakeholders in the transition to urban sustainability.

Keywords: urban energy; energy optimization model; urban planning; urban system; energy planning; energy technology

1. Introduction

Cities account for about two thirds of global primary energy consumption, which offers significant potential to optimize renewable energy production and enhance energy efficiency in urban planning. For example, a careful consideration of building site orientation and other passive strategies could lead to energy savings of 20%–50% [1–3]. At the same time, the urban planning world is going through an extraordinary transition process. As Wilson [4] points out, the research interest in the domain of urban planning—after a long interval—is having a rebirth, particularly in regard to investigating the relationship between energy consumption and patterns of physical development. However, energy concepts, such as effective consumption, efficiency, distribution, and generation have not been fully integrated into urban planning, even though great potential exists in the well-established planning process [3]. Making urban planning and development more comprehensive and efficient requires a major shift from existing government-based, top-down process to more participatory, interactive, and dynamic approaches of optimizing energy and integrating resources.

"Optimizing" implies using something in the best possible way. Accordingly, one can conceptualize energy-optimized urban planning as accomplishing the best possible solution for urban and energy planning by satisfying the goal functions, which include the following criteria: (i) maximization of renewable energy, solar gain, comfort, participation; (ii) minimization of CO_2 emissions, energy demand, cost, and pollution [5,6]. Although there is ample evidence of applying the goal functions in the developed world, significant challenges exists in site and context-specific dynamics of any given planning project. However, Kanie *et al.* [7] suggests a departure from the "one-size-fit for all" approach and involve locally-oriented energy optimization approaches—based on Millennium Development Goals (MDGs) and diffusion potential of Sustainable Development Goals (SDGs).

Given the ever-increasing complexity of urban energy planning tasks, there is a need for innovative frameworks, methods, and tools [8]. A good number of studies have concentrated either on individual energy sources or a life cycle approach [9]. Several studies revealed that only a few systems are incorporating energy transitional dynamics in urban planning. While a few topical urban energy issues, including energy efficiency and solar energy integration in urban planning were studied under different urban configurations and scales (e.g., [4,10–12]), the energy optimization issue remains largely an open topic of discussion, especially in the urban planning context of developing countries.

The complexity of efficient energy resource use in urban planning of a developing nation requires an innovative approach to optimize utilization of renewable energy resources and technologies especially in the context of countries unique profiles. Many developed country integrate energy in urban development policies, at least in principle. The European Commission, for example, recognizes the importance of integrated planning within the broader agenda of sustainable urban development [13]. Similarly, the participation of developing countries is also a need to undertake green energy initiatives in order to reduce long-term CO_2 emissions without compromising economic prosperity and environmental sustainability [14,15]. Many developing countries, like Bangladesh, currently set their priority on green growth trends with a focus on urban energy adaptation to climate change [16,17].

Bangladesh is one of the countries where per capita energy consumption remains relatively low, even after 40 years of independence. However, energy demand is growing faster, along with expansion of economic activities and prosperity. As of May 2011, the estimated daily demand for electricity was about 5500 MW, whereas the actual average generation capacity was about 4500 MW [18,19]. This gap is largely due to fuel supply shortages, as locally available natural gas is used about 86% for thermal based electricity generation [20]. The government of Bangladesh has set a target of sourcing 10% of electricity from renewable resources by 2020. However, the progress in renewable energy initiative is very slow and its potential of integration in urban planning is often overlooked [21]. A good mix of sustainable energy policies and strategies is crucial to address both supply and demand side of energy management to accomplish development goals.

Bangladesh is one of the most densely populated countries in the world with an increasing demand of energy in urban areas. By 2050, the country's population is estimated to be about 200 million, of which 40 million will live in urban areas [17,22]. The capital city Dhaka is located in the central part of Bangladesh and lies between EL (90°20′ and 90°30′) and between NL (23°40′ and 23°55′) and is expected to be one of the highest urban concentrations in comparison to all big cities of the South Asian region (Figure 1). Resource constraints, such as shortage of land and energy, are deteriorating the quality of urban life in Dhaka, much like the problems face by many other megacities in developing economies. Resource efficient urban development, therefore, could play an important role in achieving local sustainable development goals that would fit well with the MDGs.

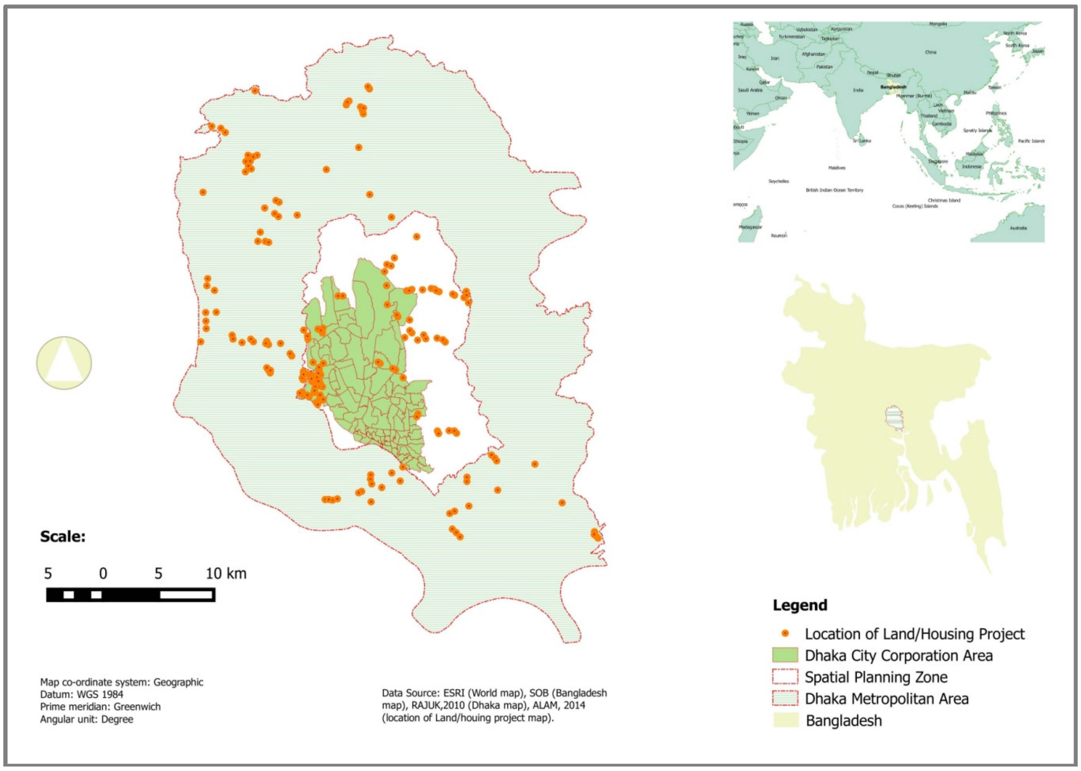

Figure 1. Location of residential settlement development projects.

To address the urban planning and energy use issues, this study explores potential of energy-optimized urban planning to efficient resource use in development of urban residential settlement in Dhaka (Bangladesh). The questions framing this study include: (1) What is the current state of energy optimization in planning of residential settlement development projects in the Dhaka city? (2) How could an energy-optimized urban planning conceptual framework contribute to energy resource use efficiency and urban planning in Dhaka city? This study specifically focuses on electricity dynamics and residents' mobility issues. However, it does not include the whole spectrum of energy-related urban planning issues. Findings related to these research questions would help to formulate future strategies and policy inputs for the urban residential settlement development planning along with efficient resources use in the context of Dhaka city and many other cities in the world with similar settings.

2. Background of Energy-optimized Urban Planning

The growing climate change and energy security concerns have led to a significant increase in sustainable urban planning discourse. From its emergence in late nineteenth century, urban planning has been considered to be a combination of both science and an art [23]. The definition of urban planning varies between both in the academic literature and real practical world. However, complexity theory provides the possibility of integrating the "science"and "social practice" of planning [24]. At the local level, urban planning also overlaps with environmental planning and urban management. It also has non-linear loops with city politics and, therefore, cannot be conceptualized as a purely technical process.

Urban planning has three levels—(i) micro (individual buildings); (ii) meso (groups of buildings, which make up neighborhoods or districts); and (iii) macro (city or region) scale. Energy efficiency and renewable energy optimization is just one dimension of sustainable urban planning [25]. Similarly, the sector-specific urban project fields comprise: (i) building engineering; (ii) utility services; (iii) urban planning; and (iv) transportation management [26]. However, the way towards low energy or optimized urban systems must simultaneously emphasize both residential building energy consumption and the transport energy consumption of residents [27]. Given the complexity of urban residential settlement development, appropriate management of such a system requires knowledge of its boundaries, resources, interactions, surroundings, and thresholds [28,29]. No specific level (e.g., city, neighborhood and building) could stand alone; rather, each of them must be considered as a part of a broad urban system [30]. Therefore, a clear multidimensional system approach is essential for contributing to further urban development.

Energy optimization is a complex urban planning task within the context of the 3E pillars (*i.e.*, environmental, economical, and social) of sustainable development and such would be highly complex within the vision to a low carbon future [31]. In fact, most of the assessment frameworks or tools from a broad vision of sustainability include significant components of energy-optimized urban planning. Some of these tools are already in use or under development on the urban and building level, but there is still a lack of widely applicable Neighborhood Sustainability Assessment (NSA) tools. The application of developed NSA tools like LEED-ND (USA), DGNB (Germany), BREEAM (UK), and Green Township (India), are limited by multiple barriers, such as being voluntary, causing economic burdens for implementers, tool complexity, ambiguity, and their bias towards expert knowledge [32–35]. However, the frameworks and guidelines of these tools could facilitate further progress in the context of energy-optimized urban planning.

Urban systems are understood as complex open systems; planning for such systems, therefore is also complex and often must include a long-term vision [24,36]. In this regard, Dosch and Porsche [37], identified three major concerns—balance among diverse sectors, complexity of rebuilding, and the inclusion of stakeholders—that need to be tackled in order to achieve efficient planning. The urban energy system is a socio-technical system that combines the processes of production, transportation, processing, conversion, distribution, storage, and end-use [38]. One significant challenge within such a process—the "paradigm change of so-called fossil based energy systems"—may be due to the emergence of renewable technologies ([39], p. 62). Several authors and experts have also highlighted that the integration of such a shift that demands a "whole-system" thinking. However, the basic features of integrated energy planning are similar to those of the current energy planning and environmental planning practices that include approaches like integrated assessment, life-cycle assessment and integrated resource planning [40]. Accordingly, urban energy planning should follow a holistic approach, which allows for alternative decision making processes by appointing optimizations, simulations, and suitability measures [41]. These suitability measures should be evaluated by summarizing key variables of large data sets and facilitating communication, interpretation and decision-making [42,43]. To this end, the vision for sustainable urban settlement development should consider a bottom up approach where urban stakeholders can participate, monitor and negotiate the key planning variables.

This paper begins by reviewing the theories and concepts of energy-optimized urban planning, urban systems, and efficient resource use. A conceptual model that we call the "EnUp" model is then presented along with a brief elaboration. We then apply the "EnUp" model to an empirical case study on Dhaka city's residential settlement development system. The case study uses the analytical frameworks of system analysis and grounded theory to process our data, which consists of systematic in-depth key informant interviews, relevant literature, and one of the authors' own experiences as an urban planner and a long-term dweller of Dhaka city. We end with a discussion of the local barriers to energy optimization and how those might inform optimization planning in other urban contexts.

3. Methodology

Within the scope of this study's methodology, we begin with an introduction to our proposed conceptual framework "EnUp" model along with the review of similar framework and model concepts. Following this our assessment method, results of the data analysis are discussed to explain the feasibility and adaptation strategies of the "EnUp" model in the context of Dhaka city.

3.1. Conceptual Framework: The "EnUp" Model

One must stress the need to include energy-conscious strategies at every stage of a planning process [25]. Nevertheless, the first step in achieving a long-term goal and comprehensive planning procedure is to establish a conceptual framework [40]. Several models and frameworks have been proposed to integrate energy optimization into urban planning. In this section, we briefly introduce a few of them, point out their strengths and weaknesses, and then introduce a draft of our own model.

Centric Austria International (CIA) introduced a methodological framework called Energy Integrated Urban Planning (EIUP) with the intention of helping cities address local-level energy problems on short and long-term strategies and action plans [44]. This methodology is a very broad vision of urban planning rather than an early design of urban residential settlement planning projects. Similarly, Yeo *et al.* [9] proposed an E-GIS-based Decision Support System (DSS) concept of energy-optimized urban planning that integrates and is built from of several urban databases. Although the system was able to be applied at the scale of a city district, it was not able to address larger urban systems and also lacked suitable evaluation measures. Mirakyan and De Guio [40], drafted a generic integrated energy planning procedure, which consist of four main phases of planning activities to be used with respective stakeholders. However, this framework's unit of analysis did not consider the urban meso scale (*i.e.*, neighborhoods) and mainly focused on territorial energy planning. Amado and Poggi [11], proposed a four-step methodological framework called Solar Urban Planning, which has also been tested at the urban meso level. However, this framework did not specify different urban stakeholders and excluded a residential mobility analysis. Similarly, Hachem, *et al.* [5], proposed a solar optimized neighborhood design methodology in the context of Canadian cities. Both of these studies have concentrated only on solar urban planning aspects from the designer's perspective without considering mobility issues. Still other studies have also proposed approaches and concepts variously called Municipal Energy Planning (MEP) [45], Local Energy Planning (LEP) [46], or Community Energy Planning (CEP) [47], but all of these mostly focused on the technical aspect of energy discourse. In summary, the gaps that collectively remain in the foregoing models include issues of scale, sectoral integration, and stakeholder's participation; an integration of these different proposals is important to establish a complete framework for the urban professional. Accordingly, we have drafted a conceptual framework called the Energy-optimized Urban Planning Model (hereafter referred to as the "EnUp" model) that addresses efficiency at the urban residential neighborhood level (Figure 2). We focused on the residential sector because it is the largest energy consumer, both in the context of our study (Dhaka) and in many other developing countries, more generally.

From the conceptual point of view and extensive discussions on the process of energy optimized urban planning [11], and integrated energy planning [40], the "EnUp" model adopts a systematic and comprehensive planning approach, which can be divided into four main steps as follows:

$\underline{Step\ I : Defineinterventionagendaandenergyconcept}$: This is the initial step where the local, context-specific matters (e.g., municipal policy, housing markets) have to be considered. An effective exchange among project related stakeholders should be facilitated with question and answer sessions. This step is helpful for problem identification, future needs assessments within the specific system boundary, and interactive communication among the stakeholders.

$\underline{Step\ II : Siteanalysisandenergyfactorsestimation}$: Detailed information on the built environment, socio-economic issues, and other needs have to be collected and analyzed along with energy consumption and renewable energy potentials. The results should be able to critically illustrate the significance of energy optimization needed in the next steps.

$\underline{Step\ III : Alternativedecisionandenergy\text{-}optimizedplandesign:}$ Based on analyzed results and design requirements, several goal-dependent planning options have to be formulated and simulated. The new plan's provisions, standards, and regulations should also consider urban system functionalities, sectoral linkages, and governance processes rather than only concentrating on the goal of energy optimization. The participation of urban stakeholders is very crucial at this step. Experts and planners should facilitate the whole process in an integrative and interactive way with stakeholders providing critical insights into local requirements, standards, and regulations.

Step IV : Implementationandevaluation : Though the new model result should, at this point, be considered as a comprehensive output, the planning process must nevertheless still include implementation and evaluation. Therefore, workable implementation and active evaluation measures have to be set up alongside the interactive participation of interested stakeholders.

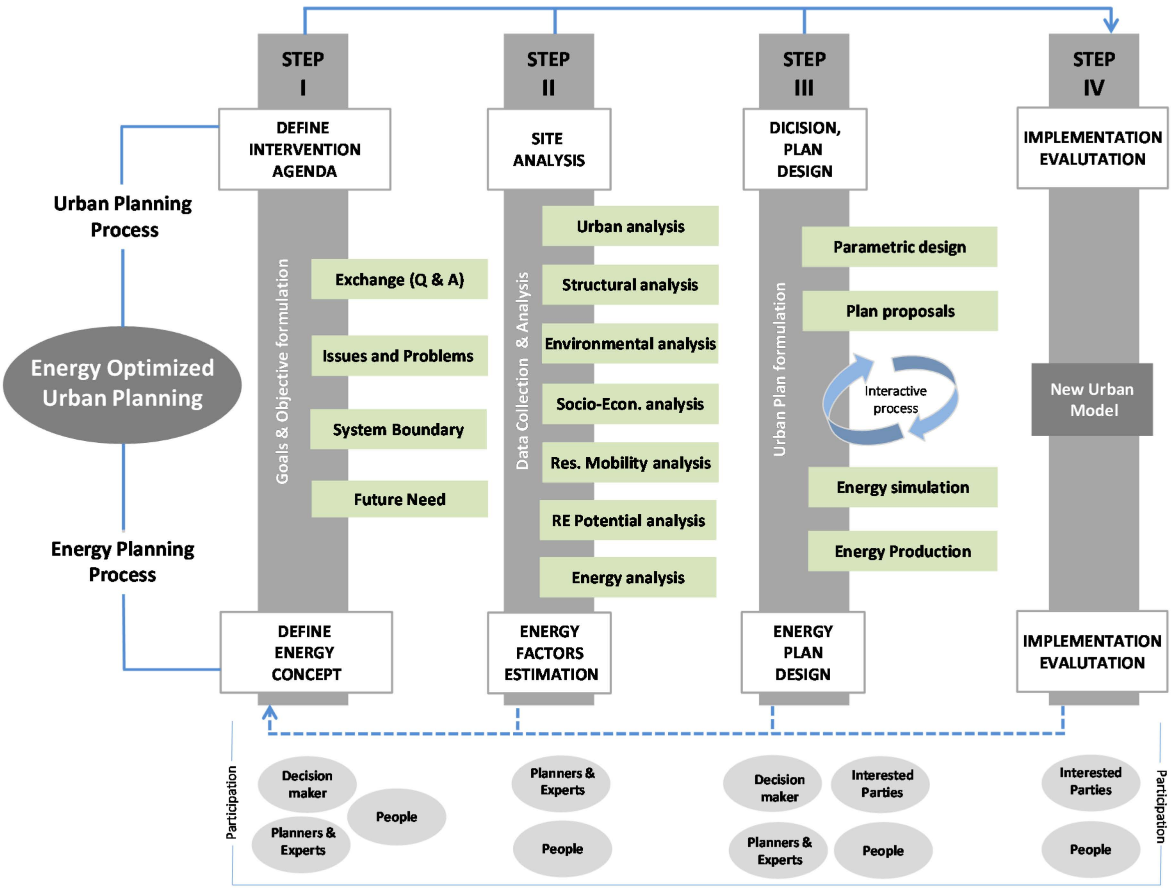

Figure 2. "EnUp" model"—A conceptual model for energy-optimized urban planning. Source: authors draft.

Notwithstanding the above steps, the "EnUp" model is not functional without appropriate methods and tools for performing both urban- and energy-planning tasks. Several scholarly articles have mentioned that the methods and tools (e.g., [34,48,49]) for supporting urban planning process are available worldwide and already popular to experts, planners and other stakeholders. A good number of methods and tools for integrated energy planning are either available or currently under development [40]. Furthermore, it can be argued that there are still a few methods and tools (for a review, see [40,41]) that are available for facilitating the initial definition phase. The "EnUp" model proposes a parallel combination of two domain specific methods and tools so that an exchange of options and limitation can be communicated among urban stakeholders. The comprehensive goal function of energy-optimized urban planning also could be addressed within the broad vision of sustainability.

The emerging complexity of urban systems has already indicated that the interdisciplinary efforts are necessary, along with early integration of stakeholder's participation in decision-making at every level and scale [3,30]. After a critical review of 58 pilot cities, the EU [50] noted that "An integrated urban planning process should involve significant experts of various urban departments from the very beginning". Accordingly, the "EnUp" model also emphasizes the need for stakeholder participation at every step of planning process.

3.2. Assessment Method, Data Collection and Analysis

The "EnUp" model included several urban system, sectors and stakeholders. Therefore, multi-step procedures were used to gather relevant data, including closed- and open-ended questioning with key informants (e.g., officials, urban planners, architects, developers, and researchers) in collecting and analyzing the data. A critical review of several secondary sources was also conducted and includes Rajdhani Unnayan Kartripakkha (RAJUK) planning documents, reports, scholarly articles, and many more. In addition, in-person, phone, and mail surveys were administered to respondents in order for the quick gathering of multi-source information—both on urban planning and energy planning in the context of residential settlement development of Dhaka city. Finally, a total of 15 in-depth, in-person interviews were conducted, and were composed of two parts: (i) general topics and (ii) expert assessment on the "EnUp-model" potential.

(i) The first part of the key informant interview covered general topics, such as the residential settlement development project approval processes, regulatory frameworks, major challenges, and future efforts needed. The text analysis software package MAXQDA was used to conduct systematic coding of interview transcripts and secondary documents. We followed Knigge and Cope's [51], approach to cluster informants' responses in a code system, which revolve around the research questions. A comprehensive actor analysis was conducted by appointing a systematic actor mapping method called "mind tool". Three steps are involved a final actor map (see Section 4.1.3). The first step in actor analysis is to identify all related actors in the residential settlement development business. The second step is to conceptualize their power, influence, and interest with a focus on energy-optimized urban planning. The final step is to figure out the most important actors and record this analysis on an actor map.

(ii) The second part of the key informant interview gathered expert opinions on each action of four planning steps that contained in the "EnUp" model. During each interview, we also noted which tools and methods the informant used in practice for performing each planning action (e.g., Figure 2). We adopted Moffatt *et al.* [52] as a systematic guideline for a structured assessment process that helps to accumulate common understandings among on different indicators. In calculating the aggregated value, which expresses the state of individual planning steps, we used the following formula:

$$AgV = \frac{\sum_{i=1}^{n}\left(\frac{\mathrm{TAS}_j}{\mathrm{AN}_j}\right)\times 100\mathrm{R}_i}{\mathrm{X}} \text{ We have } TAS_j = \sum_{t=1}^{n}[\mathrm{S}]\,\mathrm{A}_t \quad (1)$$

where AgV = aggregated value of each step (%), A_t = individual activity identification number (t → "1 to n"), S = individual score of each activity (S → "1 to 5") , TAS_j = sum of scores of all actions in step j, AN_j = total number of actions in step j (j → "1 to n"), R_i = respondent identification number, (i→ "1 to n"), X = total number of respondents. Finally, a Spiderman diagram is appointed to visualize all aggregated results of the assessment (see also Section 5.1).

4. Results of Case Study

4.1. Current Status

Dhaka is projected to become the world's third largest megacity by 2020, and has a 38% (13.4 million) share of Bangladesh's urban population [43]. The total area of greater Dhaka is 1460 sq.km, and is topographically surrounded by low-lying flatlands and wetlands [22,53]. Dhaka was a small rural settlement until the end of 16th century. In the last 400 years, the city has experienced several urban development and expansion exercises under different governance regimes [54]. After the independence of Bangladesh, Dhaka began to expand in all directions in order to meet the needs of the new capital city [55]. However, this urban planning and development has always followed a haphazard and almost unregulated pattern.

4.1.1. Urban Planning and Development

An emerging megacity such as Dhaka is a prime example of a complex and dynamic systems that might be represented by the interactions between socio-economic and environmental processes at both the local and global scale [56]. Being a former British colony, Bangladesh, as well as Dhaka, are still following the same planning hierarchy of colonial urban planning practices. Since independence, Dhaka city has grown both in horizontal and vertical directions, mostly without maintaining any development and planning guidelines [57]. The first master plan for Dhaka was enacted in 1993. Recently, the government introduced the Dhaka Metropolitan Development Plan (1995–2015) based upon a target population of 15 million residents. However, the projected metropolitan population of 15 million has already been surpassed. Due to huge pressure of urbanization, the city development patterns are dominated mostly by informal characteristics including substandard structure, narrow/irregular street, poor utility infrastructure networks and inadequate basic services [58]. In this regard, comprehensive action is required to recognize the urban dynamics of Dhaka and to allocate or control its growth activity in a sustainable manner [54].

Formal urban development projects follow similar patterns, whether they are carried out by both the public and private sector. Most common initiatives include land development or residential township projects which are often followed by site and services development [58]. After these developments, the land area is simply divided into roughly symmetric plots with the provision of a gridiron road layout and allotted for residential and commercial activities. Apart from site development, the private sector also develops individual apartment buildings sporadically in negotiation with the landowners.

4.1.2. Residential Settlement Development and Energy Concerns

The residential settlement typology in Dhaka city is dominated by an informal system. Only about 27% of the total residential settlement is developed under the provision of formal private and public sector land/housing development regulations [59]. A recent study has identified 181 residential settlement development projects in the greater Dhaka city area (Figure 1), which has been initiated by both the private and public sector [60]. Several sources confirm that only a few projects would meet the formal planning standards and development regulations.

Dhaka city is facing acute housing demand due to continuous urbanization. As a result the housing business has grown progressively over the last 20 years (Figure 3). Since 2006, the main reasons for exponential growth of the real estate business are mostly related to land market issues, such as vacant land scarcity, higher land value, land speculation, and remittance inflow for land purchases. The increasing number of nuclear families and growing public confidence about living standards in apartment building also have played significant roles [61]. Studies have estimated that the housing demand may persist or even rise in the coming years. For instance, by 2020 more than five million new residents need to be accommodated in Dhaka [58]. At the same time, however, the transformation of residential settlement quality in the existing planned residential settlement schemes of Dhaka city has mostly deteriorated due to huge violations of predefined land use, illegal plot subdivisions, and increased building heights [57,62]. The changes and violations in terms of building use, land use, and population density have also had serious impacts on utility service facilities (e.g., electricity, water) and transportation in both inter-neighborhood and other surroundings. For instance, an urban planner—who is involved in a private sector residential settlement development project—mentioned during a key informant interview " ... the current population density threshold for residential area is only 350 person/acre but in reality you will find far more than that".

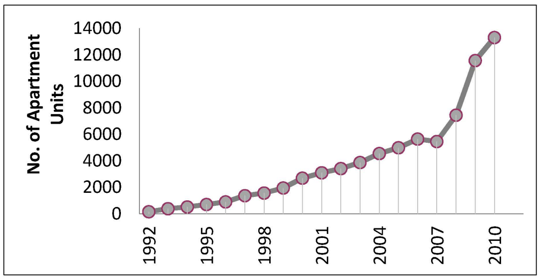

Figure 3. Trend of Housing Business. Source: authors' own illustration based on housing statistics of the Real-estate and Housing Association of Bangladesh (REHAB). A comprehensive database has been compiled by REHAB which has been confirmed in REHAB [63].

In addition to growing housing demands, the national energy demand increased by 10% from 2009 to 2011. Compounding this challenge, the buildings of Dhaka city show an unsustainable and inefficient energy consumption portfolio [64]. One of the electricity providers of Dhaka city (e.g., DESCO) reported that the residential sector alone consumes 48% of total electricity consumption (Figure 4). The city has a total peak electricity demand of about 2000 MW, but the available supply in a typical day is only 1000–1200 MW [65]. Therefore, power blackouts are a common phenomenon that causes a multitude of inconveniences for urban inhabitants [66].

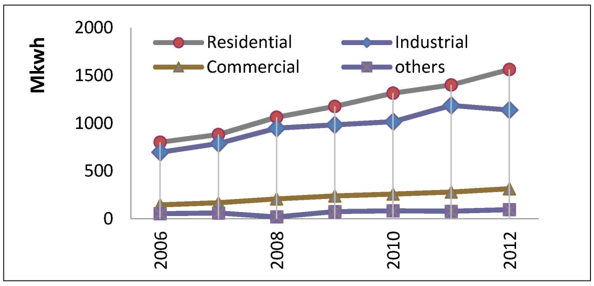

Figure 4. Electricity Consumption Trend. Source: authors' own illustration according to the electricity consumption data of Dhaka Electric Supply Company (DESCO) Limited. DESCO is one of the largest electricity providers in greater Dhaka city.

Apart from many factors of energy generation, one should realize that the existing planning and building regulations hardly address the energy efficiency measures and consumption dynamics, focusing instead on density and development control. There is, in fact, no building energy code in Dhaka [58,60]. In addition, residential mobility in Dhaka city is highly dependent on private vehicles due to insufficient public transportation options [67]. Consequently, enormous traffic congestion and malfunctioning traffic management systems often cause massive delays in covering small distances, resulting in both higher travel time and energy use.

4.1.3. Actors Involved in Residential Settlement Development

Both the public and private sectors are involved in residential settlement development projects. While the public sector mostly acquires land, subdivides it, and installs some basic infrastructure, and then allocates lots to individual buyers, the private sector purchases (or grabs), develops, and subdivides large amount of land into plots and then obtains approval from the Capital Development Authority (RAJUK) for selling them to the end users [59,60]. According to the register of RAJUK, the total number of private land and housing developers in Dhaka city in 2012 was 108. Although more informal developers are doing small-scale informal land and housing development projects, those are not registered in the RAJUK record book. There is a separate list of registered private developers who are constructing only apartment buildings.

In total there are more than 181 residential settlement development projects that can be identified in grater Dhaka, but only few projects have been approved by the electricity and transportation authority [60]. Unfortunately, even responsible electricity and transportation regulatory agencies do not maintain or share any record about the application and approval of residential settlement development projects (Table 1).

Table 1. Administration of residential settlement development projects by urban agencies.

Sector/Agency	Applied Projects	Approved Projects
Electricity suppliers	No records	Information could not be collected
Transport Authority	No records	02
Gas suppliers	20	06
Department of Environment (DoE)	27	02
Dhaka city corporation	No record	06

Source: Compiled by author and varified with Alam [60].

RAJUK is the main government entity responsible for administrating the approval process of residential settlement development projects but, under the provisions of existing regulatory requirements, there are 16 additional organizations that are also involved in the approval process of these projects. Therefore, due to varied interest and power relations among of different agencies, the approval process has become a complex one (Figure 5). The management strategies and working approaches make it difficult for the developers to meet all the requirements of urban agencies. The absence of a one-stop service or common platform is perhaps one of the main reasons hampering the governing of residential settlement development projects. The complexity of the approval process, particularly for utility services (e.g., electricity, water, transportation), is frequently noted due to the absence of prescribed steps; agencies, accordingly are free to administrate according to their own management and development policies. In many case, the developers failed to fulfill all the requirements of approval, and as a results, some projects (managed by both the private and public sectors) are simply handed over to the end-user with only very limited or no provision of utility services.

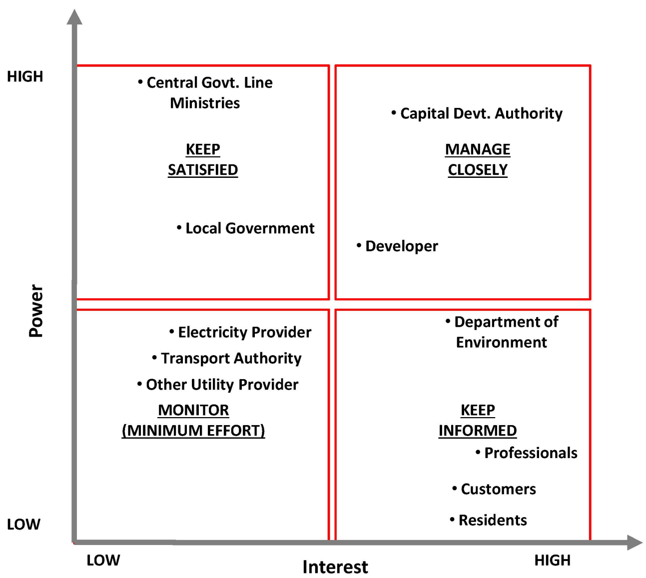

Figure 5. Actor map in the residential settlement development business. Source: authors' own illustration based on the Field survey (2013), Note: detail description on Actor Mapping can be found in http://www.mindtools.com; and the actor's participation in urban residential settlement development projects has been discussed from the perspective of good governance in Masum [59].

Moreover, this complicated process tends to discourage altogether urban stakeholders' participation in any form of energy-optimized urban planning. Apart from the organizational actors, the targeted customers and affected residents express increasing interest for affordable housing, but due to huge demand and limited supply of housing they have almost no negotiation power. Unsurprisingly, then, their level of participation in the planning and development process also remains relatively low.

Evidence from several advanced countries show that the local government is one of the major actors in energy efficiency and management activities. In the context of Dhaka city, one can also observe a relatively weak position of municipal authority in terms of energy-optimized urban planning. This is common in other cities of Bangladesh and largely the result of a top-down governance system.

4.1.4. Regulatory Frameworks in Place

One major area that remains under-researched is that of the inefficiency of law and regulation to support energy dynamics [3]. Evidently, sufficient energy-optimized parameters have not been established in current planning regulations and practices, especially for developing countries' urban residential settlement development plans.

Like many other developing countries, Bangladesh is also struggling with insufficient and ineffective regulations for ensuring a better living environment [68]. In Dhaka city, the present planning and building regulations are mainly focused on the control of density and development control-related issues rather than urban development and building construction practices [58]. The approval process for new individual building construction involves only two steps: (i) land use/planning clearance; and (ii) building permits, but the residential settlement development projects approval process involves more regulatory measures. A brief review of such regulations is presented in Table 2.

Table 2. Potential and Weakness of legal framework.

Law/Policy and Enactment Year	Potential	Weakness
Town Improvement Act (TIA Act 1953)	Basis for building code and land use clearance	Prescribed land use enforcement is optimized in case of privately owned land
Dhaka Metropolitan Development Plan (1995–2005)	Identified suitable areas for residential settlement development	Lack of detailed guidelines and even created conflicts with other regulations; need to address energy parameters
Environmental Conservation Act, 1995	Legal basis for environmental assessment at least for large scale residential settlement projects, the small scale project also should be realized	Mostly focused on industrial and transport pollution control; soft punishment of violation (<5 years imprisonment or fine <$1500 USD or both)
Private Housing Project Land Development Rule, 2004	Focused on social, physical and environmental standards; Keep approval provision by several urban authorities including energy agencies and transport authority	Almost no provision of punishment imposed other than old legal provisions; Lack of common understanding among different urban stakeholders. No project has approved under this rule yet
Public–Private Partnership Flat Housing Policy (2008) on public vacant land	Encourage innovative solutions to control land supply, mobility and urban form	Increase gentrification and flood risk
Metropolitan Building Construction Rules, 2008	Introduced FAR which to enhance environmental, social and aesthetic values	Limited focus on energy efficiency issue in terms of building design, material use and construction management
National Renewable Energy Policy, 2008	Promote renewable energy with an objective to meet 5% of the total power demand by 2015 and 10% by 2020	Urban sector has all most ignored whereas more focused on rural electrification
Real Estate Development and Management Act, 2010	Basis to impose innovative energy related strategies as it is dealing with management of property transfer and registration	No punishment provision due to violation, no price control mechanism; No concerns about conservation of ecological sensitive area
National Green Building Code, 2012	Instrument to reduce energy consumptions, water use and environmental impact by regulating building design and constructions	Still under consultation which subject to government approval; No significant punishment assigned for violation

Source: Authors' own review, KI opinions survey (2013) and inspired by Alam [60].

An urban planning professional described the state of the regulatory framework for approving residential settlement development projects accordingly: "Even for going through all the processes could be a long and difficult one as there are many open, overlaps and loopholes in the regulations. There are almost no prescribed steps or process how to evaluate the public sector housing/land development projects. It should be mentioned here that the Capital Development Authority (RAJUK) itself doing major public sector residential settlement development projects".

5. Results and Discussion

5.1. Potential of "EnUp" Model in the Context of Dhaka

5.1.1. State of Individual Planning Steps

The "EnUp" model contains a comprehensive set of actions that need to be performed in order to achieve energy-optimized urban planning. In the context of Dhaka city, this study has conducted a systematic assessment to realize the current state of planning, with particular emphasis on residential settlement development projects. In what follows, we present the feedback from key respondents, which has been aggregated after translating all individuals accumulated actions into scores by following the four different planning steps of the "EnUp" model (for detail on the method see also Section 3.2). The final result shows that the site analysis and energy estimations (step 3) have gained an average aggregated rating of 50%, whereas the remaining three steps did not exceed a 40% rating (Figure 6). Collectively, these results highlight the need of further initiatives.

In current practice, the urban site analysis activities for urban residential settlement projects are commonplace in Dhaka city. The energy estimation capabilities perform only on a very basic level without considering any dynamics of innovations or technologies. The existing methods, models, and tools for conducting different activities will be discussed in the next section.

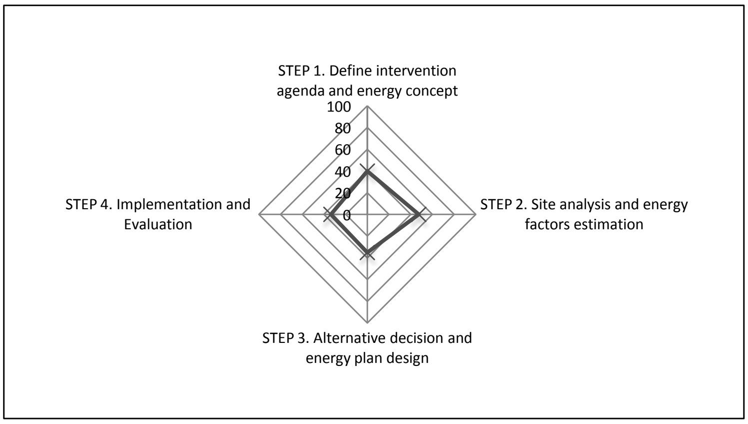

Figure 6. Status of major steps of "EnUp" model. Source: field survey (2013).

5.1.2. Methods, Models, and Tools that Work for the City

A good number of methods, models, and tools are available for realizing energy-optimized urban planning and development. EnergyCity—a central European project—has identified eight modeling tools for reducing energy consumption and CO_2 emissions at the micro level of planning [69]. In addition, some integrated models and tools have also been applied and established in consideration of land use, transportation, and energy dynamics (e.g., [70]). After analyzing survey data and published sources, this study argues that the poor use of different methods, models, and tools is one of the significant challenges for adapting an energy-optimized urban planning framework in the context of Dhaka city, and Bangladesh more generally.

Most of the modeling and analytical tools always demand an extensive and/or updated database support [41]. In the context of Dhaka, control over development is hampered by insufficient exercise of regulations, shortage of skilled manpower, absence of database management (DBM) systems, and lack of new technology/tools adoption [68]. The urban planning and management agencies reported that they are using few methods and tools such as Geographical Information System (GIS) or Remote Sensing (RS) for development planning and topographic surveys. Additionally, most of the initiatives are active on a temporary project-by-project basis, and may disappear after the end of any given project. Urban planners, architects, and other environmental professionals are using some advanced methods and tools, but only on an informal and voluntary basis. They should be supported with more modern and updated tools in order to deliver high quality professional services.

In Dhaka, the local government has limited technical and financial capabilities and, therefore, mostly seeks support from the central government. Municipal capacity building, therefore, must be built by improving expert knowledge, and by providing effective tools and support programs to implement the issue of energy in urban planning.

Though the electricity supply companies continue to progress towards digital database management and the adaptation of energy planning tools (e.g., Windmill, Equipment Record Card software), their efforts remain insufficient for performing urban energy planning at the neighborhood level. The transportation regulatory authority is mostly dependent on traditional models, methods, and tools, except some very basic traffic modeling and GIS application. The informal and weak public transportation system adds further challenges for estimating transport related parameters through the use of well-established models and tools.

Despite these challenges, progress can be seen in case of individual new buildings construction. The Institute for Building Efficiency [71] factsheet shows 11 registered or certified LEED projects in Dhaka city. Additionally, REN21 [39] reported that developing countries like Bangladesh have continued to implement methods/tools and capacity building for future shares and amounts of renewable energy generation in recent years.

5.1.3. Challenges and Barriers

There are a lot of challenges and barriers for implementing energy-optimized urban planning in Dhaka city. The challenges and barriers revealed from the empirical data analysis can be grouped into three broad categories of governance, technical, and regulatory, although some cross-cutting issues resist exclusive categorization (Figure 7). Nonetheless, the governance-related challenges are prominent (46%). These include general issues such as corruption, co-ordination, evaluation, and stakeholder participation. There are also some exceptional factors, such as ignorance of developers and complexity in the approval process. For example, an urban researcher commented that "Urban agencies are very segregated and mostly do not have any common and clear understanding in their activities. Residential land and housing development is a process where at least 16 authorities are involved directly and all of them have their own mandate and end of the day it is very become complex". An executive official who works for one of the energy authorities mentioned that" energy planning is becoming an interdisciplinary task but yet in Dhaka city the authority does not have the culture of integrated work. The electricity sector is not out of that. We think that if the urban planning decisions are well established and manageable it could help energy planning task a lot".

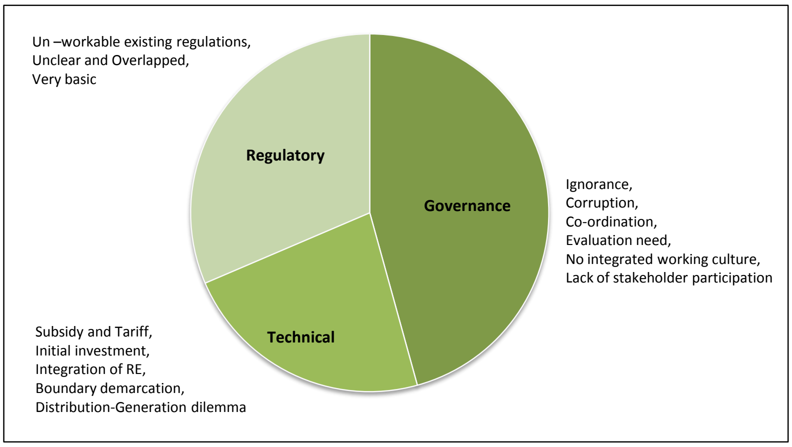

Figure 7. Assessment result about challenges and barriers. Source: field survey (2013).

The technical (23%) challenges and barriers include issues, such as traditional energy subsidies, cheap grid electricity, high initial investment for renewable energy system installation, integration complexity for renewable energy, huge housing pressure, boundary-related complexity, and the dilemma of energy distribution and production. Illustrating this are the comments of a RAJUK official, who said that "Dhaka city is a densely populated city such that none of the energy measures that are adopted in many other countries in the world–are not feasible here". The electricity companies, however, are conducting some digitalization and database management in order to plan better customer services. The government has some programs for encouraging renewable energy and energy efficiency issues in Dhaka but often face difficulties due to the inter-agency generation and distributions dilemmas.

Finally, the regulatory-related challenges and barriers (31%) include the fact that existing regulations are frequently unworkable, very basic, unclear and overlapping with each other. For example, a land and housing developer mentioned "there is a need to have clear regulations to include energy issues and other utility services in case of housing and land development projects. The private sector is doing a lot to tackle housing need of the citizens but the public agencies should help by offering easy provisions of infrastructures". The inter-agency coordinations, furthermore, are not well-functioning with current regulatory framework—RAJUK (as a leading agency) is not capable of bringing all stakeholders together. In fact, no specific practice in RAJUK exists yet to systematically integrate energy issues into urban planning. Recently the floor area ratio (FAR) was introduced for density control, but complaints often emerge due to the huge housing pressure.

5.1.4. Where Further Efforts are Needed

The estimated solar PV potential is very significant in Dhaka city even when only considering building rooftops. The city offers more than 10 sq.km of bright rooftops on which nearly 1000 MW electricity can be generated with stand-alone PV applications [54]. The feasibility of wider deployment of alternative options for energy-optimized urban development, such as energy-plus buildings, are significant in the context of Dhaka city. This is because a huge number of new constructions and urban developments are going to take place in the coming years [58]. Our empirical survey data analysis also found a good number of responses indicating that the need to address technical issues (41%) is more important than either governance (36%) or regulatory (23%) issues, respectively (Figure 8). Such technical efforts include the determination of thresholds, recognition of energy dynamics, consideration of neighborhood contexts, innovations in new technology adaptation, and integration of energy concepts at the early design stage in urban residential settlement development projects. The need for capacity building, strong local government, a supportive private sector, and balance between the public and private sectors are frequently mentioned as areas of potential governance improvement.

There are also some comments on regulatory efforts such as clear regulations for housing projects, review of planning-control instruments, and re-adjustments of laws and rules.

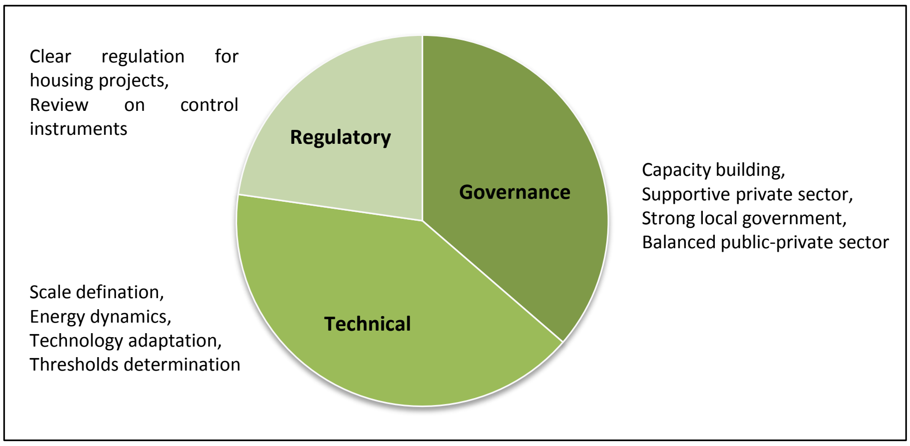

Figure 8. Assessment result about needs for further efforts. Source: field survey (2013).

The need for an integrated approach can be observed in the statement of an urban planning professional who said that "the hard principal is to fulfill all legal provision and negotiation with the urban and environment management concerns".

The renewable energy potentials of urban area deserve a close look in terms of policy concerns. Renewable technology, like solar PV, is one of the most feasible options for all over the country but most of the efforts to install of solar technology disseminations are only concentrate in the rural area. Apart from solar energy, there are other technologies that have also matured enough to support energy efficiency measures and energy production in urban Bangladesh, but generally are not getting enough attention by the decision-makers. Of course, the future urban energy efficiency and renewable energy production initiatives also should realize that how to deal with related challenges such as grid integrations, management, subsidies, and market issues.

6. Conclusions and Policy Implications

Energy-optimized urban planning is a growing concept in moving towards green economy and energy transition in rapidly-urbanizing megacities like Dhaka. This has a great potential to address local energy concerns and cities' climate change challenges, such as increased energy demand, clean energy production, and transition towards a green economy. This study investigated and discussed the comprehensive urban planning process in regards to efficient resource use and developed a conceptual framework for energy-optimized urban planning called the "EnUp" model. The "EnUp" model was applied in a developing country perspective and the potentials of urban energy optimization were assessed systematically, along with identifying challenges/barriers and future efforts need.

Using system analysis and grounded theory approaches, we analyzed the current state of urban residential settlement development projects along with energy planning of Dhaka city. The case study was conducted along with key informant interviews and review of secondary sources. The results show that the adaptation of a comprehensive approach like the "EnUp" model is both possible and necessary to address the urban growth challenges of Dhaka city. The model can also serve as a guide for sustainable urban development in Bangladesh, considering current challenges and barriers that need to be addressed. From a governance viewpoint, there are needs for capacity building, strong local government, a supportive private sector, and balance between the public and private sectors. What is needed is a common urban platform, a transition to an inter-agency, collaborative working culture, and stakeholder engagement. Additionally, there is a need for regulatory efforts, such as improved and stronger policies for housing projects, a review of planning control instruments, and the re-adjustment of laws and rules. From a technical point of view, highly-skilled manpower, customized tools, and high quality data must also be integrated into planning efforts.

In the future, we forsee addressing many other relevant issues. First, we will finalize some study indicators by following a systematic process and considering local context of energy-optimized urban planning. In fact, the set of indicators should reflect the issue of signigficant implementation of energy optimization goals in the urban planning process. Then we plan to validate the “EnUp”model after completion of case studies specifically with Dhaka's residential settlement development projects. The potential of the “EnUp” model could also be tested for the energy-optimized retrofitting of existing urban built areas or industrial/business areas. Similarly, the “EnUp” model may also be applicable in other cities around the developing world. However, one must critically analyze the state of local urban planning and the energy context beforehand, as there may be both similar challenges and differences regarding the sorts of future needs identified in this article; either way, local investigations and detailed guidelines for implementation of energy-optimized urban planning. Our methodology would be helpful in exploring the local context of energy-optimized urban planning and could contribute towards local Sustainable Development Goals, as well as larger global issues in a more comprehensive way. The results of this study contribute to the field by better documenting and visualizing the possibility of a comprehensive urban planning and energy planning process in developing countries and useful insights to policy makers, planners, developers, and urban stakeholders interested in transition to urban sustainability.

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