Can Fast Urban Growth Be Low-carbon? Sub-Saharan Cities Towards New Territorial Strategies

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Abstract
Sub-Saharan Africa is now experiencing rapid urban growth. Considering that buildings account for most of the world's greenhouse gas emissions, guiding such an urban development towards low carbon is vital. With such an aim, this study focuses on the case of Lusaka, the capital of Zambia, which is subject to a rigid and partially outdated urban development system and lacks a deliberate policy addressing sustainable urban growth.
This study aims to demonstrate how, in the context of Lusaka, renewable technologies can contribute towards a net zero strategic territorial development. First, a systematic review of the integration of residential rooftop solar photovoltaics (RPVs) was undertaken; second, an in-depth purposive-sampled semi-structured interview with a local expert was conducted; third, the combination between renewable technologies and urban development was explored; finally, the systematic integration of RPVs based on the following four factors was proposed: (1) site coverage, (2) floor area ratio, (3) number of storeys, and (4) dwellers' density.
Results show a range of feasible hybrid solutions for addressing Lusaka's electricity needs. Furthermore, this study demonstrated that on-site energy production can influence both horizontal and vertical dimensions of buildings of energy self-sufficient energy communities: the maximum number of storeys, the maximum number of dwellers and, consequently, the floor area ratio. This study aims to pave the way towards regulated, strategic and sustainable territorial development by illustrating an easily replicable strategy.

Keywords: Fast urbanisation; Territorial strategies; On-site energy production; Sub-Saharan Africa; Lusaka

1. Background

Cities consume three-quarters of natural resources and generate equivalent greenhouse gas (GHG) emissions (Pardo Martínez et al., 2021). Today, one of the main challenges is reducing such consumption to tackle climate change. Climate resilience, energy performances of old and new buildings, and responsive urban planning—with well-defined and structured objectives—

have been identified as significant determinants of this challenge (IEA, 2022b). While spatial planning can facilitate climate actions (Hurlimann and March, 2012), 'a larger number of environmental crises take place in countries subject to high and rapid rates of urbanisation, fast urban sprawl, urban informality and weak urban governance' (Myers, 2011), often happening in developing regions of the world.

In 2020, despite hosting one-fifth of the world's population, Africa reported the lowest carbon emissions per capita (IEA, 2022b). This favoured condition, however, did not exempt the African metropolises—currently 'the epicentre of global urbanisation' (UN/ECA, 2017)—from being affected by the rampant consequences of global climate change and from facing global[ised] cities' challenges (Bini and d'Alessandro, 2017). In the period to 2050, the African continent is indeed forecasted to face the biggest floor area expansion in the world, with its building stock reaching about 50 billion square metres, doubling its current size (IEA, 2022b). The critical condition lies in the emergence of large cities despite low national income levels, leading to difficulties in providing essential services and infrastructures (Kriticos, 2019) and amplifying the already present effects of climate change, particularly in urban areas (IEA, 2022b).

1.1 . Zambia: climate change actions towards sustainable urban development.

Zambia, among other countries in the Sub-Saharan region, has been dealing with the sustainability of urban growth for a long time. In 1994, the nation embarked on a strategy of sustainable urban expansion to address the challenges of poverty, inequality, a declining economy and the government's limited capacity to provide essential public services (Makasa et al., 2010; UN-HABITAT and UNEP, 2009); during that period, the Ministry of Local Government and Housing (MLGH) developed the National Housing Policy, which called upon the private sector and local communities to engage in the planning and execution of 'sustainable human settlement projects' (UNDP, 1997). In subsequent years, the nation implemented various programmes, engaged in several initiatives, and developed new legislation to address the complexities of rapid urbanisation (Myers, 2011; UN-HABITAT and UNEP, 2009; Musonda, 2018). In 2015, the enactment of the Urban and Regional Planning Act No. 3 was expressly designed to provide additional guidance for implementing sustainable urban and rural planning and development (MNDP, 2020). In 2016, the nation amended its constitution to incorporate sustainable development as a fundamental national principle, aligning with the objectives outlined in the 2030 Agenda (MNDP, 2020). Therefore, the formulation of the National Urbanisation Policy in 2018 was driven by the need to tackle the challenges highlighted by the United Nations Sustainable Development Goal (SDG) 11: '(a) proliferation of informal settlements, (b) absence of supportive city form and functioning system of cities, (c) weak institutional and regulatory framework for urban development' (MNDP, 2020). As such, the National Housing Policy underwent revision in 2019, and an Implementation Plan was formulated to support 'sustainable, decent and affordable housing for all' (MNDP, 2020).

Notwithstanding persistent endeavours to address climate concerns via legislative measures and policy development, Zambia remained classified as a nation particularly susceptible to climate change in 2021 (COMESA, 2021). Consequently, the government presented a climate action plan to the United Nations Framework Convention on Climate Change (UNFCCC) in 2022, aiming to adapt to climate change and mitigate greenhouse gas emissions. This plan would then aim to decrease emissions resulting from future growth, as the International Energy Agency (IEA, 2022b) reported.

Even though institutional and regulatory processes are being used to introduce SDGs (MNDP, 2020), in Zambia the diversification of the energy mix should be improved in order to deal with the effects of climate change (McPherson et al., 2018; Ismail, Metcalfe, and McPherson, 2019;

MNDP, 2020; Imasiku, 2021; IEA, 2022b; Kapole, Mudenda, and Jain, 2023), such as drought and flood cycles, which show the limits of the over-reliance on hydropower (McPherson et al., 2018; Ismail, Metcalfe, and McPherson, 2019; IEA, 2022b; Kapole, Mudenda, and Jain, 2023). In 2019, the nation's reliance on hydropower accounted for 80.6 %; other energy sources were thermal (coal-powered) at 10.1 %, heavy fuel oil at 3.6 %, solar energy at 3 %, and gas, standby gas and diesel turbines at 2.8 % (MNDP, 2020). Although the country is indeed favoured by natural potentialities being abundant in hydropower and sunlight—it has the second-highest potential for solar power in the world (UNDP, 2014)—, which leads to excellent outputs both in hydroelectric and photovoltaic (IEA, 2022b), numerous hindrances to the full adoption of renewable energies were individuated: policy and regulatory barriers, as well as technical, institutional, financial and awareness-related issues (UNDP, 2014).

1.2 . Lusaka.

Materialising the dynamics mentioned above, the province of Lusaka boasts the highest urban population growth in the country (MNDP, 2020); it is considered one of the continent's fastest-growing cities (Ismail, Metcalfe, and McPherson, 2019), 'projected to at least double between 2020 and 2050' (UN-Habitat, 2022). The city's urban growth tends to follow an extensive model, expanding through new developments on the peripheries rather than within existing areas (USAID, 2018), leading to an urban sprawl which provokes overconsumption of resources (IRP, 2018), which in turn can not be guaranteed by institutions, often relying on outdated laws (Musonda, 2018). The rigid urban development system triggered several urban challenges, further amplified by the weaknesses of urban development institutions (Chigudu, 2021), showing the evident lack of a deliberate policy addressing urbanisation challenges and accompanying sustainable urban growth (Chigudu, 2021).
In line with the Zambia Vision 2030 (RoZ, 2006), Lusaka raised its policy profile on climate change adaptation and mitigation (LCC, 2016; IEA, 2022b). The effects of climate change, however, are hitting the city: low seasonal rainfall leads to load-sheddings (periods of planned energy supply disruption) lasting numerous hours per day (Jürisoo et al., 2019; Imasiku, 2021), a situation in some cases persisting more than one year (Jürisoo et al., 2019). This phenomenon triggers the users' demand for alternative and more reliable energy technologies, independent from the national grid, often fossil fuel-based (Jürisoo et al., 2019; Kapole, Mudenda, and Jain, 2023).

2. Research hypothesis and arguments

The previous section shows the efforts of local, national and international actors to face urban and climate challenges. However, the Zambian regulatory landscape does not keep pace with the evolving built environment (Chigudu, 2021), and *business-as-usual* can not cope with existing and future challenges. Climate change-aware regulations, as supported by the National Policy on Climate Change of the Republic of Zambia, must be prioritised (RoZ, 2016).

2.1 Hypothesis

Energy challenges and urban developments are strictly linked (Castán Broto and Baker, 2017; Perera, Coccolo, and Scartezzini, 2019; Bouzarovski, 2020). The paper hypothesises that the supply of energy from renewable sources can become a parameter to control Lusaka's urban morphology for a net zero territorial development.

2.2 Arguments

The urban form, the cradle of buildings' behaviours, can be a tool to face the challenge of cities' emissions. Different types of urban settlements have been demonstrated to be drivers of spatially contextualised combinations of carbon emissions (Baiocchi et al., 2015), and the study of urban-scale development strategies must be prioritised to reach net zero (Scognamiglio, Garde, and Røstvik, 2014). The physical texture of cities, once defined, is not flexible enough to allow future changes and creates long-lasting interdependencies among land use, transport, buildings, energy demand and carbon emissions (Güneralp et al., 2017); this condition calls for an urgent 're-direction of practised planning paradigms towards more sustainable spatial development' (Stoeglehner, Niemetz, and Kettl, 2011).
At present, spatial production is strictly related to the spatial dimension of energy challenges (Castán Broto and Baker, 2017), with cities across the globe significantly influenced by energy demand (Bouzarovski, 2020) and energy demand significantly influenced by cities' forms (Perera, Coccolo, and Scartezzini, 2019).
In Zambia, a country experiencing an insufficient national energy supply (fuelled by fast horizontal urban expansion and climate change effects), energy demand is expected to increase rapidly (McPherson et al., 2018; Ismail, Metcalfe, and McPherson, 2019). In such a context, integrating renewable energy technologies during urban development becomes of primary importance. In this regard, previous literature identified fundamental parameters: Salat (2010) proved that the urban form has the potential to halve the overall energy consumption and carbon emissions, while other studies reported that urban form, the density of building and population, envelopes' technology, systems' efficiency, inhabitants' behaviour and sources of energy impact energy performances (Strømann-Andersen and Sattrup, 2011; Yang et al., 2012; Stewart and Oke, 2012; Steadman, Hamilton, and Evans, 2013; Di Bernardino et al., 2015; Salvati, Coch Roura, and Cecere, 2015; Ignatius Wong, and Jusuf, 2016; Güneralp et al., 2017; Salvati et al., 2019; Hadavi and Pasdarshahri, 2020). Moreover, urban morphology parameters, such as land coverage and average building height, are found able to anticipate the urban energy performances (Salvati et al., 2019), and the urban form is found to impact the energy system in terms of cost, system autonomy and renewable energy integration (Perera, Coccolo, and Scartezzini, 2019).
Consistently, policymaking must ensure a radical reduction in greenhouse gas emissions, considering energy-related matters at the beginning of the urban planning process (Shi, Fonseca, and Schlueter, 2017). Improving the energy mix and generation from renewable sources can be the key to closing the gap in energy deficit in Lusaka (MNDP, 2020; Imasiku, 2021). In this regard, focusing on energy demand management (Grubler et al., 2012) would shift the interest from the national scale—often focusing on the supply— to the local management (Neves and Leal, 2010), following the trajectory of an energy chain already moving in the direction of decentralised and micro-scale infrastructures (Bouzarovski, 2020), levers for managing carbon emissions (McPherson et al., 2018).

2.3 Research questions

1. Is integrating residential RPVs with an urban-scale approach feasible in Lusaka?
2. How can on-site energy production be a tool to control urban expansion in both vertical and horizontal dimensions?

3. Methodology

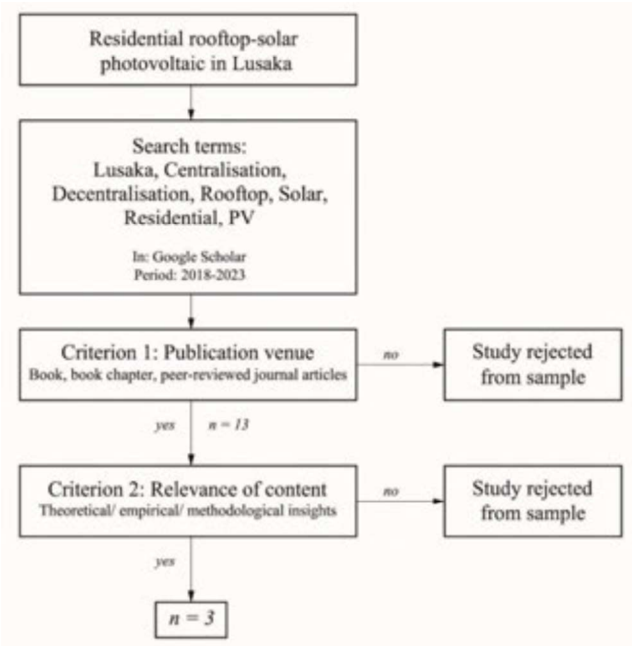
Seeking answers to the research questions will contribute to developing a net zero strategic territorial development. In light of the observations made by previous literature, this study will: a) investigate the supply of energy from renewable sources in terms of rooftop-solar power generation only; b) consider the supply of energy from renewable sources as a tool to face Lusaka's urban challenges.

This study investigates both centralised and decentralised RPV systems serving residential areas in Lusaka. Nevertheless, solar energy mini-grid systems have not been considered because of their previously verified unsustainability in the Zambian context (Stritzke and Jain, 2021; Kapole, Mudenda, and Jain, 2023). Stritzke and Jain (2021) investigated the solar mini-grids in Sinda and Mpanta, while Kapole, Mudenda, and Jain (2023) recently investigated a list of initiatives owned by both public and private institutions: Magodi mini-grid in Lundazi, Katamanda mini-grid in Chipangali, Chitandika mini-grid in Chipangali, Muhanya mini-grid in Sinda and Chibwika mini-grid in Mwinilunga. The studies observed that, although solar mini-grids are considered one of the most viable solutions to provide energy from renewables to the part of the population without access to electricity, they pose insurmountable sustainability-related limitations in the context of Zambia—in financial, environmental, and social perspectives. The public and private-owned projects were found to be financially unsustainable, especially in rural areas; in urban areas, their minimum financially sustainable residential tariff is estimated to be much above the one of the national utility ZESCO, and a lack of technical expertise hinders their implementation (Kapole, Mudenda, and Jain, 2023). The majority of the projects, however, have been defined socially—in terms of users' satisfaction and availability of electricity 24/7 (Stritzke and Jain, 2021)—and environmentally sustainable (Kapole, Mudenda, and Jain, 2023).

This premised, the study included a multiplicity of methods:

1) A systematic review (Grant and Booth, 2009) was conducted to comprehensively evaluate previous integrations of residential RPVs in Lusaka. Google Scholar was used to identify potentially relevant studies, and the terms 'Lusaka', 'PV', 'centralisation', 'decentralisation', 'rooftop', 'solar', and 'residential' were searched simultaneously. Only studies written in English from 2018 to 2023 have been selected due to the inner limitations of previous renewable technologies. The search yielded 24 works from various disciplines and venues: 12 articles, four reports, four theses, three book chapters, and one working paper. The selection was refined by including only books, book chapters and peer-reviewed journal articles, resulting in 13 pieces of work. A second refining criterion was adopted, excluding works that did not describe Lusaka's RPV strategies. Finally, the three relevant works meeting all the criteria were considered for further analysis (McPherson et al., 2018; Ismail, Metcalfe, and McPherson, 2019; Imasiku, 2021). This limited number shows an overall lack of consolidated literature on this topic.

Figure 1. Methodology adopted for the selection of articles.



2) Due to the minimal scientific work produced on the topic as of October 2023, one in-depth semi-structured interview was conducted the same month to compensate for the lack of scholarly information. The interviewee, selected by purposive sampling technique (Taherdoost, 2016) according to role and experience, was an expert in the development of renewable energy projects operating in Lusaka, holding previous experience in the development of solar projects and working for a Ministry from more than five years at the time of the interview. The interview was conducted remotely using the Google Meet tool. The respondent was requested to answer 14 open-ended questions. The interviewer encouraged free-flowing discussion; the interview lasted 1 hour and 10 minutes. Answers have been first recorded, upon explicit consent, and later transcribed. The generated transcript has been cross-checked with the recording to maintain data integrity. Finally, the RADaR technique (Watkins, 2017) was applied for qualitative data analysis.
3) Finally, the terms of combination between renewable technologies and urban development have been explored, delivering a framework for urban-integrated PV.

4. Analysis and findings

4.1 Reasons for a change

The free-flow discussion with the expert allowed the authors to gain a broad understanding. He reported that the severe load sheddings of 2014, 2015 and 2016 pushed national and international agencies not to over-rely on hydropower due to its evident limitations. Currently, the attention of the Ministry in which he operates is on the development of energy efficiency guidelines; officials are conducting ‘studies to learn how energy efficiency can be useful in urbanisation’ in order to establish ‘how to conserve energy at the point of use’. This understanding catalysed the authors’ attention, *de facto* confirming the relevance of investigating the transitional—situated in a particular location and moment—interactions between renewable energies and urban strategies in Lusaka.

What emerged from this interview is the pivotal importance of costs and returns for the people for whom the energy systems are made: can they afford them? In this geographical and social context, future policies have to benefit everyone because ‘people are part of the system as well’; in this light, activities ‘to understand the social impact of grid extensions’ are indeed promoted. The expert further confirmed that Lusaka is now subject to a fast increase in constructions, which follows a model of horizontal expansion moving in the direction of peri-urban areas; a higher electricity demand is consequent. Despite being ‘one of the best system configurations, cost-effective’, solar power generation was initially considered a non-competitive alternative due to the low tariffs of the national energy supply. ‘Previously, the cost of energy was cheap, and people could afford to waste the energy. But now, as the cost of energy is slowly going up, people will be more interested in solar. We should talk about it now.’ The Energy Regulation Board, in fact, lately promoted an increment of tariffs on a 5-year programme (ERB, 2023). Four incremental tariff bands are set to regulate consumption in the ‘Residential’ category: while the users subject to the lowest tariffs are typically not motivated to change energy sources, those subject to higher tariff bands are looking for cheaper alternatives. Accordingly, the implementation of RPVs in low-income communities would face a multiplicity of challenges—including the possibility of accessing the less expensive tariff band and the inadequacy of the building stock—; differently, middle- and high-income neighbourhoods are ideal targets for implementing RPV systems. Integrating solar power generation into users’ buildings would contribute to a) demand for less energy from the national supplier and b) avoid the physical extension of the energy grid and the related challenges.

4.2 Centralisation or decentralisation in Lusaka?

Ismail, Metcalfe, and McPherson (2019) evaluated the feasibility of centralised and decentralised (both on-grid without battery-storage components and off-grid with battery-storage components) solar power generation, estimating the urban rooftop potential in Lusaka and rural Zambia, to address Zambia’s electricity deficit ‘attributable to climate disturbances and the nation’s rapidly increasing electricity demand’ (Ismail, Metcalfe, and McPherson, 2019). The study found that centralised solar generation can produce generation/cost ratios comparable with existing hydro generation ratios. In Lusaka, the study showed that a fully decentralised approach would be much more costly than the existing rate. Several hybrid generation scenarios were thus investigated, with the 70 % centralised and 30 % off-grid decentralised scenario best addressing the electricity shortages until 2030. In such a scenario, solar energy would provide affordable power and fast planning/implementation while offering autonomy to users. The study further highlighted the importance of collaboration between local and national institutions to develop long-term renewable energy legislation (Ismail, Metcalfe, and McPherson, 2019). McPherson et al. (2018) also showed that up to 50 % of total electricity demand could be met by decentralised solar photovoltaics—20 % more than what was found by Ismail, Metcalfe, and McPherson (2019)—if the energy generated is directly used. In this hybrid process, the system’s low transmission expansion cost would outweigh the high storage costs (McPherson et al., 2018).

Imasiku (2021) tested the applicability of solar photovoltaic performance for grid-connected households in Lusaka (on-grid decentralised approach with battery-storage components). This hybrid model was demonstrated to alleviate the power load sheddings, meeting the demand

when hydroelectric could not, with users able to sell the excess power to the utility (configuration of a power purchase agreement). A two-bedroom house was considered for the load sizing, and the system included one residential RPV module of 1.6m^2 (China Sunergy-Nanjing CSUN285-60M), one inverter (Jiangyin HR-240P-AC/BbP)—both with low efficiency, chosen to mirror the availability on the Zambian market—and a storage battery connected to the direct current. Technical information on the model design (system design, losses, technical characteristics of photovoltaic module and inverter, system cost, etc.) is not relevant to the purpose of this study. Finally, Imasiku (2021) demonstrated that the two-bedroom household's nominal peak-hour energy consumption for middle-income earners in Zambia could be successfully met by on-site energy generation.
In summary, the feasibility of both centralised and decentralised (on-grid with/without batteries, off-grid) RPV energy generation in Lusaka was evaluated, showing that:

a) Hybrid solutions best address the need for electricity. The 70 % centralised and 30 % off-grid decentralised (with battery-storage components) scenario is the most favoured regarding costs and planning/implementation feasibility. The off-grid component was observed to be feasible up to 50 % if the solar power is directly supplied.
b) On-grid decentralised systems (with battery-storage components and commercial low-efficiency inverters and modules) have been demonstrated to meet the supply, allowing users to sell the energy surplus to the utility grid.
c) The interviewed expert confirmed that one system can not be chosen *a priori* over the other one. In the case of households using electricity only during the daytime, for example, a storage battery would not be necessary because of direct consumption. A battery would be necessary if a relevant percentage of the activities were to be operated at night. Operations to test the average loads would be thus needed before a realistic choice.

This study provided thus a range of feasible alternatives. It is important to note that the complex modelling of individual connections would have gone beyond the scope of the study, which is instead interested in understanding the feasibility of integrating residential PV with an urban scale approach.

4.3 Self-sustaining urbanisation: an approach towards net zero.

While the range of feasible renewable technology alternatives was investigated and reported in sections 4.1 and 4.2, the terms of combination with the urban development are presented below. Urban form factors have been previously recognised to have a pivotal role in urban planning and renewable energy integration and will thus be considered in this study section. The relevance of the urban form factors used in Perera, Coccolo, and Scartezzini (2019)—which investigated the influence of urban form on the grid integration of renewable energy technologies and energy systems design—has been cross-checked with other consolidated studies (Ratti, Baker, and Steemers, 2005; Salat, 2010; Strømann-Andersen and Sattrup, 2011; Yang et al., 2011; Stewart and Oke, 2012; Steadman, Hamilton, and Evans, 2013; Di Bernardino et al., 2015; Salvati, Coch Roura, and Cecere, 2015; Ignatius, Wong, and Jusuf, 2016; Güneralp et al., 2017; Salvati et al., 2019; Hadavi and Pasdarshahri, 2020; Ahmadian et al., 2021); the factors considered were: the Ground Floor Area [m^2], the number of storeys, the Treated Floor Area [m^2], the Sky View Factor (SVF), the Floor Area Ratio (FAR), the Site Coverage [%] and the Form Factor (FF). However,

a) a low-rise horizontal expansion characterises the context of Lusaka; for this reason, the authors evaluated the inclusion of the Sky View Factor as unnecessary for this study;

b) both the Treated Floor Area and the Form Factor are related to the thermal envelope (Perera, Coccolo, and Scartezzini, 2019), of which the investigation would go beyond the scope of the study;
c) in the cross-checked studies, particular importance was given to the density of people living in a given space, which is strictly related to land use and land surface; this factor has thus been considered in this study.

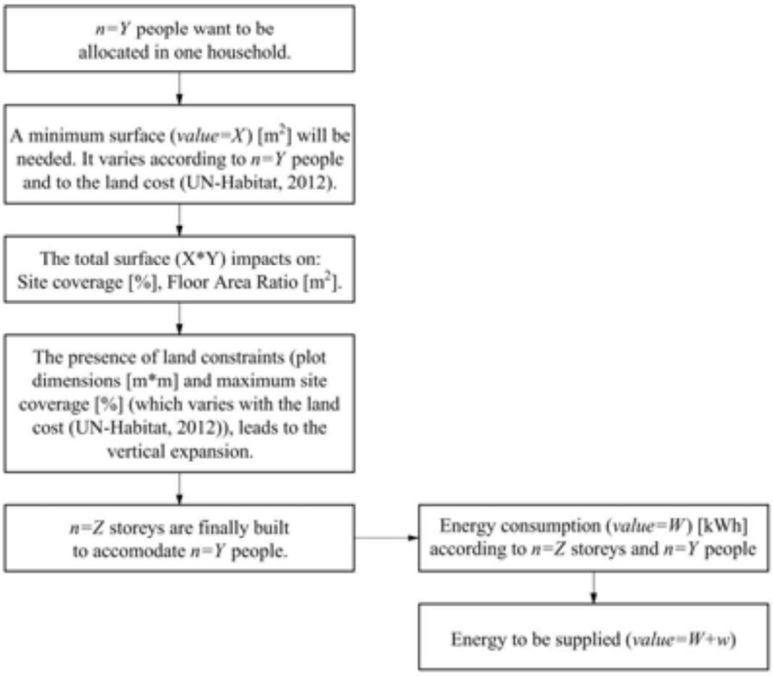
From an urban planning perspective, the following factors have been considered: Site Coverage [%], Floor Area Ratio (FAR), number of storeys, and dwellers' density. Regulations and standards related to:

i) land use and cost, plot size, site coverage, distances from boundaries and ratio area/population can be found in UN-Habitat (2012) and Chitengi (2015);
ii) the size of windows and habitable rooms can be found in the Public Health Act (GoZ, 1995);
iii) the height of buildings can be found in the Urban and Regional Planning Act, n. 3 of 2015 (GoZ, 2015);
iv) the installation of solar panels on buildings can be found in the Urban and Regional Planning Act, n. 3 of 2015 (GoZ, 2015), and on ERB website (2023).

4.4 Conceptualisation

Urban expansion, driven by housing demand, is here investigated in terms of horizontal and vertical growth, considering dimensional factors. Horizontal growth adds more ground floor space and directly relates to site coverage; vertical growth, in contrast, maintains the same ground floor space and site coverage but increases the number of storeys and the floor area ratio (Perera, Coccolo, and Scartezzini, 2019). These factors behave as variables, varying with the number of dwellers (constant) by following the minimum standards in the Public Health Act (GoZ, 1995). Finally, urban form and human behaviours lead to a specific energy consumption, which consequently suggests the amount of energy that should be supplied (Figure 2).

Figure 2. Logic representation of the process.



4.5 Upside-down perspective

This study aims to understand if on-site energy production can be a parameter to control and moderate urban expansion. The authors thus investigated the on-site energy generation as a constraint for horizontal and vertical expansion by capping the maximum energy consumption by a building to the maximum amount of energy produced. By a domino effect, this essential constraint can influence all the previously considered urban factors (Figure 3). Finally, the maximum on-site energy production could influence the maximum number of storeys, the maximum number of dwellers and, consequently, the floor area ratio. This approach shows how the number of storeys and the allowed floor area ratio increase by raising the maximum on-site energy production. The novelty of this system lies in relating often unrelated metrics towards a regulated and strategic territorial development.

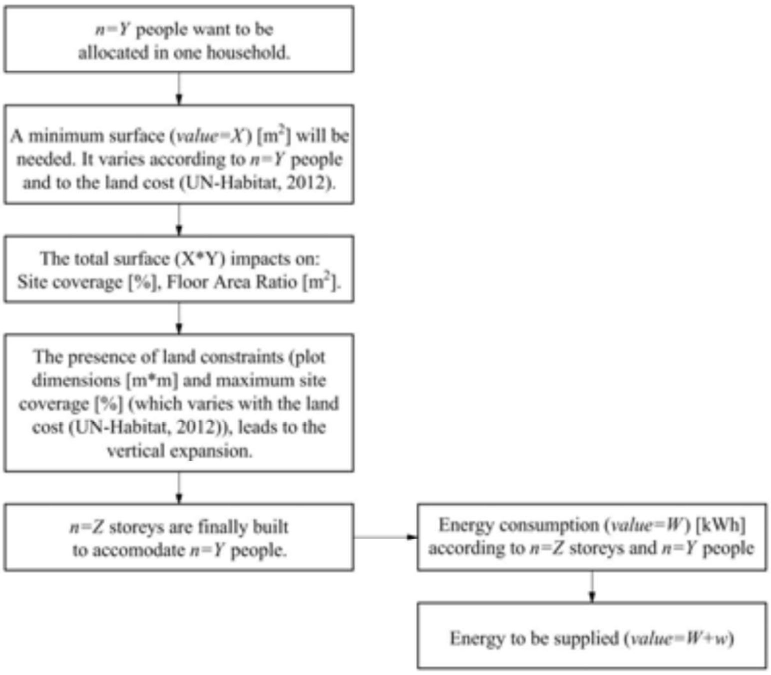


Figure 3. Theoretical prototype for urban-integrated photovoltaics.

4. Impact, significance and outputs

Can the current Zambian building regulatory landscape answer urban and climate challenges? Chigudu (2021) was critical: the rigid urban development system triggered over time several urban challenges, showing the evident lack of a deliberate policy addressing urbanisation challenges and accompanying sustainable urban growth; climate change-aware regulations, as supported by the National Policy on Climate Change of the Republic of Zambia, must be now prioritised (RoZ, 2016).

This study aimed not only at demonstrating that the implementation of renewable technologies can become a tool towards the development of urban strategies in the context of Lusaka but also at moving attention to the possibility of using the already ongoing horizontal expansion as the cradle for its own change (as explored in Fiacco and Talamini, 2021). The originally unfavoured condition was overturned: the fast horizontal expansion did not represent just an urban challenge but was exploited to ensure energetic independence for new urban developments. If applied at a large scale, this approach would address both urban and energy challenges by moderating horizontal and vertical growth through clean energy production. This urban-driven energy transition would limit the exposure to the risks deriving from fast urban development and climate change, further contributing to the development of pathways not yet investigated. The study demonstrated that the maximum on-site energy production can influence the maximum number of storeys, the maximum number of dwellers and, consequently, the floor area ratio; the on-site energy production could be linked to vertical and horizontal growth. The novelty of this approach was indeed in the innovative relating of metrics and indicators towards a regulated and strategic territorial development.

This process can a) stimulate both private and public sector to invest in on-site energy generation, especially when in connection with residential land use, paid back by the increase in FAR, with the consequent possibility to build a higher number of units and allocate a higher number of dwellers; b) relieve the national energy utility, guaranteeing supply independence to users; c) represent a reference for a future easily-replicable self-sustaining urbanisation, avoiding a blind urban development leading to energy-hungry verticalism or horizontally hyper-extended and not well-managed spaces, which would ultimately risk becoming unlivable (Lall et al., 2021).

Urban scale strategies can only be pursued through policies that incentivise the systematic integration of renewable energy sources in new constructions, raising awareness among users and providing financial incentives and support (Ismail, Metcalfe, and McPherson, 2019). Bharwani et al. (2023) explained that locally-led and sustainable urban planning can be reached by supporting the diverse stakeholders (such as city councils and local universities) to co-create priorities, goals and knowledge around specific projects, considering the lived experience of local people alongside scientific inputs. A shift from ‘government’ to ‘governance’ (Scott, 2017) is necessary, where urban governance is meant as the ‘multiple ways through which city governments, business, residents, and civil society organisations interact in managing the urban space’ (Scott, 2017).

Author Contributions

Conceptualisation: FF, GT; Methodology: FF; Investigation: FF, KJ; Writing - Original draft preparation: FF; Writing - Review & Editing: FF, GT, KJ; Visualisation: FF; Supervision: GT; Project Administration: FF, GT.

Originality

The authors declare that the content of this research was presented at the “2023 Architecture Conference ‘*Development of Climate Sensitive Building Regulations for Zambia: the need for a collaborative effort by all stakeholders’* held by the Zambia Institute of Architects (ZIA) in Lusaka (Zambia), on November 22-24, 2023.

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