Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 75 (2015) 2904 – 2909

Energy Procedia

The 7th International Conference on Applied Energy – ICAE2015

A conceptual framework for assessment of urban energy resilience

Ayyoob Sharifi[a]*, Yoshiki Yamagata[b]

[a]Global Carbon Project-Tsukuba International Office, 16-2 Onogawa,Tsukuba 305-8506, Japan
[b]National Institute for Environmental Studies, 16-2 Onogawa,Tsukuba 305-8506, Japan

Abstract

It is now widely acknowledged that climate change is occurring as a result of anthropogenic greenhouse gas emissions. Although human settlements have always been threatened by various types of risks and hazards, climate change is expected to exacerbate the intensity and frequency of many of these hazards. This could have severe consequences for supply, transmission and distribution of energy, as the driving force of the majority of economic activities in urban areas. Responsible for a significant part of the global energy consumption, cities need to be well-equipped and prepared in the face of increasing climate change induced disasters. In recent years, resilience thinking has been increasingly used for examining how cities are ready to face imminent disasters. Despite the importance of energy for effective functioning of cities, there is still a gap in the urban literature regarding the definition of energy resilience and development a framework for its assessment. To fill this lacuna, this study aims to specify the main components of urban energy resilience and develop a conceptual framework for its assessment. Drawing on an extensive literature review, this study defines energy resiliency as a range of preparation, absorption, recovery, and adaptation measures that ensure availability, accessibility, affordability, and acceptability of energy supply, transmission and distribution over time. This definition is used for conceptualizing energy resilience assessment and can be used to design an urban energy resilience toolkit. Such a toolkit should cover various energy related aspects such as infrastructure; land use, urban geometry and urban morphology; resource management; urban governance; legal basis and regulations; and social and behavioural aspects. The toolkit could be utilized by planners and decision makers to make better-informed decisions towards low-carbon and resilient urban development. The paper concludes by emphasizing that any energy resilience assessment toolkit should include criteria and indicators that address both mitigation and adaptation aspects of climate change.

Peer-review under responsibility of Applied Energy Innovation Institute
Keywords: Resiliemce; Urban Energy; Planning; Absorption; Recovery; Adaptation

* Corresponding author. Tel.: +81-29-850-2672 ; fax: +81-29-850-2960.
E-mail address: sharifi.ayyoob@nies.go.jp; sharifigeomatic@gmail.com.

1876-6102 © 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of Applied Energy Innovation Institute
doi:10.1016/j.egypro.2015.07.586

1. Introduction

The majority of world population is now living in cities and the share of world urban population is expected to steadily increase in the coming decades. Cities are the major loci of global energy consumption and continuous energy supply is essential for their effective functioning. The expected urban population increase, together with other driving forces such as lifestyle change, would have significant implications for future energy supply and demand. Unless drastic measures are taken, the projected significant increase in the global energy consumption [1] would in turn result in further emission of greenhouse gases (GHGs) into the atmosphere, thereby intensifying climate change. Climate change will result in increased occurrence of hot spells and severe and longer winters [2]. Consequently the demand for cooling and heating energy will increase and given the expected depletion of oil reserves and fuel price rises, meeting this increased demand will be a huge challenge [3, 4]. The costs of energy supply interruptions will be too high for economic growth of cities. Accordingly, the challenge ahead is two-pronged. On the one hand, as the global average temperature changes linearly with the increase in the cumulative CO_2 emissions, severe mitigation measures are needed to limit warming to two degrees [5, 6]. On the other hand, adaptation measures are also required because climate change is already occurring and will have severe impacts on the urban energy system irrespective of the future trajectories of GHG emissions.

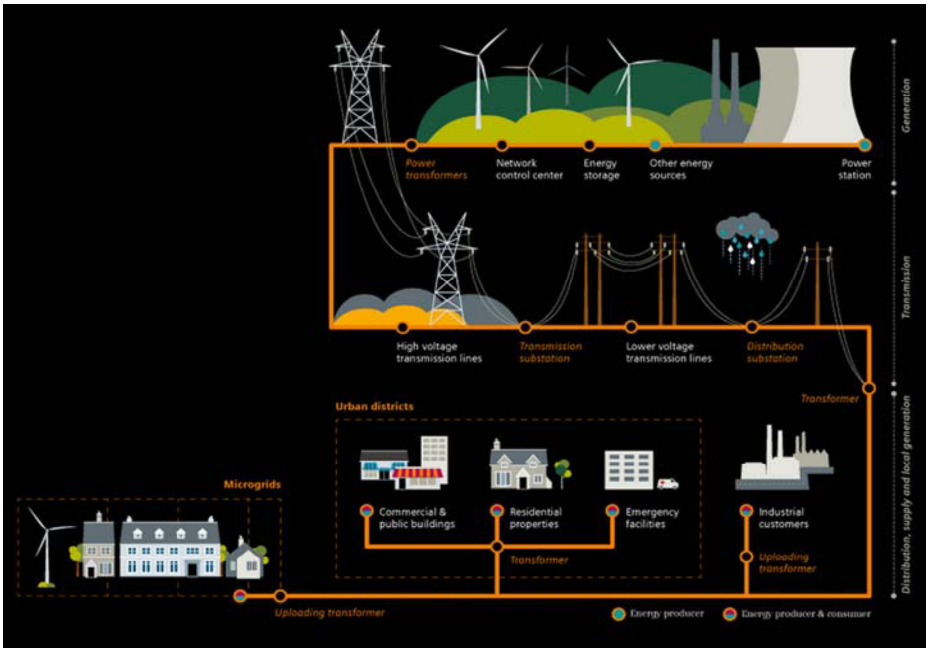

Fig. 1. An example of an energy system (Source: www.siemens.com/urban-resilience)

Resilience thinking is a concept stemmed from physics, psychology, and ecology and increasing gaining ground in urban literature and multiple individual aspects of resilience have already been addressed [7]. However, despite the importance of energy resilience for the very survival of urban areas, it is still an understudied concept and warrants further investigation. The existing research is mainly focused on single domains of urban energy resilience such as transportation [8] and green infrastructure [9]. A single and comprehensive definition of resilience that can be used across various sectors of urban energy system is still missing. In addition, supply, transmission, and distribution (see Fig 1. for an example) as the three major component of any energy system are not studied in an integrated manner. Furthermore, unlike other related concepts such as sustainability [10], no comprehensive tool has yet been developed for assessment of urban resilience, let alone urban energy resilience. Before any attempt to develop such an assessment tool it is necessary to clarify the definition of urban energy resilience and design a framework that can, in turn, guide the development of the desired assessment tool. Assessment tools can be used by planners and decision makers to track progress towards achieving the goal of transition to low-carbon and resilient urban futures. This paper is part of a broader study focused on development of criteria and indicators for evaluation of urban resilience.

2. Methods and materials

To develop a conceptual framework for urban energy resilience, this study reviews literature on related subjects such as resilience, sustainability, and energy security. A synthetic approach is taken to provide a conceptual framework that captures multiple characteristics of a resilient urban energy system. A diagram is used to show how the different components of the framework are related.

3. Urban energy resilience

The concept of resilience is tightly linked to sustainability as an umbrella concept that is aimed at maintaining socially, economically and environmentally desired human-environment interactions over time. This paper discusses the concept of energy resilience at urban level. Unless a system is resilient, climate change and its associated uncertainties and complexities could undermine the likelihood of achieving this goal [11]. Therefore, it can be stated that any sustainable system should be resilient as well [7]. For the reasons described above, energy lies at the core of urban sustainability. Reaching a desired state of urban energy requires availability, accessibility, affordability, and acceptability of energy supply required for effective functioning of cities [3, 12]. Acceptability refers to taking appropriate measures to ensure that energy is generated in an environmentally benign fashion. Before linking this four criteria with the concept of resilience, it is necessary to clarify what resilience entails. Like sustainability, various definitions of resilience exist and there is still no single, generally accepted definition in the literature. Three approaches to defining resilience include, engineering resilience, ecological resilience and adaptive resilience [13, 14]. The engineering approach conceptualizes resilience as the system's robustness and resistance against external disruption and its capability of returning to an equilibrium state in the rare cases when the tipping points are crossed. The ecological approach recognizes the unpredictability of the system and emphasizes its capability of absorbing the disturbance so that the main functions of the system are persisted. This implies that the system may return to multiple equilibrium states. The last approach is designed for describing the behavior of socio-ecological systems. This soft approach towards defining resilience acknowledges the dynamics of the system and uncertainties, and unpredictability of natural disasters. It emphasizes the system's ability of self-organization and existence of mechanisms for learning from the disaster in order to bounce forward to a better state. Therefore, in adaptive approach to resilience the system does not return to an equilibrium state. Since city is a socio-ecological system, the adaptive approach is adopted for the purpose of this study. An adaptive approach requires the system to have the ability to plan/prepare for the disaster, absorb the initial shocks, recover in a timely manner, and learn how to adapt [15-17]. Based on what discussed above definition of urban energy resilience is as follows.

3.1. Definition

An energy resilient urban system should be able to ensure availability, accessibility, affordability, and acceptability of energy supply, under varying conditions, through enhancing its ability to plan/prepare for disaster, absorb its initial shocks, recover rapidly and adapt and self-organize. A conceptual diagram illustrating the relationship between the concepts discussed here is depicted in Fig 2.

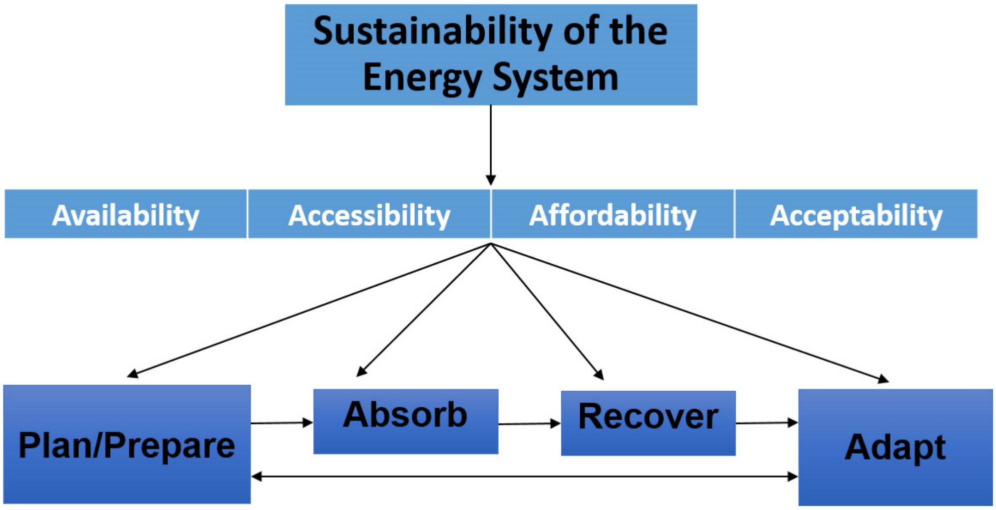

Fig. 2. Conceptual framework of urban energy resilience

3.2. Characteristics of an energy resilient urban system

In order to fulfill the requirements of the definition above, the urban energy system should entail the following characteristics. To save space, here the descriptions of the characteristics are not provided and interested readers are referred to [7, 18].

- Robustness
- Stability
- Flexibility
- Resourcefulness
- Coordination capacity
- Redundancy
- Diversity
- Foresight capacity
- Independence
- Interdependence
- Collaboration
- Agility
- Adaptability
- Self-organization
- Creativity
- Efficiency

4. A framework of criteria and indicators

In order to utilize the conceptual framework described above for assessment of urban energy resilience, it is necessary to build a matrix including various planning and design criteria that are related to energy supply, transmission, and distribution in the urban areas. Showing the details of this matrix falls beyond the scope of this paper. The matrix will divide the collected list of criteria into major categories that relate to aspects such as infrastructure; land use, urban geometry and urban morphology; resource management; urban governance; legal basis and regulations; and society and behavior. Each category will consist of several criteria which in turn may be divided into sub-criteria. The idea will be to relate each criterion to the energy resilience components and characteristics described above. As an example, street connectivity is a criterion under the category of urban morphology that is related to the plan/prepare and absorption abilities of resilience and can enhance the flexibility, efficiency, and adaptability of the energy system. Having a complete list of these criteria could enhance the decision-making capacity of planners and policy makers by showing them the potentials of each criterion and more importantly the shortcomings of urban areas. It should be mentioned that the selected criteria would address a combination of mitigation and adaptation measures and this means that trade-offs and synergies between these measures should also be clarified. This way, decision makers would be able to come up with mechanisms to maximize the synergies and minimize the trade-offs. d

5. Conclusions

Resilience thinking is important for achieving sustainable communities. If sustainability entails maintaining a desired state of generation and supply, transmission, and distribution of the energy demanded for effective functioning of urban systems, resilience to disasters will be its pre-requisite. Despite the abundance of research on urban resilience, existing literature on urban energy resilience is very limited. Given the primary role of energy related emissions in climate change and the high concentration of people in urban areas it can be argued that transformation of current urban energy systems will be crucial for climate stabilization. As an initial step to address this gap, this paper reviewed a number of the existing studies on urban resilience and urban energy systems to provide a synthetic definition of urban energy resilience. This definition, together with a set of resilience related characteristics, was used to introduce a conceptual framework for assessing the energy resilience of cities and socio-ecological systems. This framework conceptualized energy resilience of a given urban system as its ability to guarantee availability, accessibility, affordability, and acceptability of energy supply over time by enhancing its abilities to plan/prepare for disaster, absorb initial shocks, recover rapidly, and self-organize and adapt.

In order to have a more comprehensive framework it is necessary to specify how the different characteristics introduced in Section 3.2 relate to each other and fit into the framework. When fully designed, the framework could be utilized for categorizing the multitude of criteria that may affect the resilience of urban energy systems. Such an assessment framework should acknowledge that both mitigation and adaptation measures would contribute to energy resilience and make efforts to clarify the synergies and trade-offs between the measures.

References

[1] Caputo S, Caserio M, Coles R, Jankovic L, Gaterell MR. Testing energy efficiency in urban regeneration. Proceedings of the Institution of Civil Engineers-Engineering Sustainability. 2012;165:69-80.

[2] Lloyd-Jones T. Retrofitting sustainability to historic city core areas. P I Civil Eng-Munic. 2010;163:179-88.
[3] Kruyt B, van Vuuren DP, de Vries HJM, Groenenberg H. Indicators for energy security. Energy Policy. 2009;37:2166-81.
[4] Molyneaux L, Wagner L, Froome C, Foster J. Resilience and electricity systems: A comparative analysis. Energy Policy. 2012;47:188-201.
[5] Akbari H, Matthews HD, Seto D. The long-term effect of increasing the albedo of urban areas. Environmental Research Letters. 2012;7.
[6] Fuss S, Canadell JG, Peters GP, Tavoni M, Andrew RM, Ciais P, et al. Betting on negative emissions. Nature Climate Change. 2014;4:850-3.
[7] Sharifi A, Yamagata Y. Major principles and criteria for development of an urban resilience assessment index. Green Energy for Sustainable Development (ICUE), 2014 International Conference and Utility Exhibition on: IEEE; 2014. p. 1-5.
[8] Rendall S, Page S, Reitsma F, Van Houten E, Krumdieck S. Quantifying Transport Energy Resilience Active Mode Accessibility. Transport Res Rec. 2011:72-80.
[9] Alexandri E, Jones P. Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. Building and Environment. 2008;43:480-93.
[10] Sharifi A, Murayama A. A critical review of seven selected neighborhood sustainability assessment tools. Environmental Impact Assessment Review. 2013;38:73-87.
[11] Shaw A, Burch S, Kristensen F, Robinson J, Dale A. Accelerating the sustainability transition: Exploring synergies between adaptation and mitigation in British Columbian communities. Global Environmental Change. 2014;25:41-51.
[12] Sovacool BK, Mukherjee I. Conceptualizing and measuring energy security: A synthesized approach. Energy. 2011;36:5343-55.
[13] Barata-Salgueiro T, Erkip F. Retail planning and urban resilience – An introduction to the special issue. Cities. 2014;36:107-11.
[14] Wardekker JA, de Jong A, Knoop JM, van der Sluijs JP. Operationalising a resilience approach to adapting an urban delta to uncertain climate changes. Technol Forecast Soc. 2010;77:987-98.
[15] Roege PE, Collier ZA, Mancillas J, McDonagh JA, Linkov I. Metrics for energy resilience. Energy Policy. 2014;72:249-56.
[16] Cutter SL, Ahearn JA, Amadei B, Crawford P, Eide EA, Galloway GE, et al. Disaster Resilience: A National Imperative. Environment: Science and Policy for Sustainable Development. 2013;55:25-9.
[17] Linkov I, Eisenberg DA, Plourde K, Seager TP, Allen J, Kott A. Resilience metrics for cyber systems. Environment Systems and Decisions. 2013;33:471-6.
[18] Tyler S, Moench M. A framework for urban climate resilience. Clim Dev. 2012;4:311-26.

Biography

Ayyoob Sharifi is the executive director of Global Carbon Project – Tsukuba International Office. He received his Ph.D. from Nagoya University in 2013. Ayyoob's current research interests include sustainable and resilient urban development with an emphasis on minimizing the negative impacts of urban development through design and promotion of low-carbon communities.