Social Network Analysis of Building Energy and Carbon Policy Networks in Developing Countries

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Abstract. More than two thirds of countries worldwide, the majority being developing countries still have not implemented mandatory regulations to control building energy usage and carbon emissions despite the rapidly increasing building stock in these regions. Thus, it is vital to develop effective energy and carbon policies for buildings in developing countries. Developing such effective policies in turn, needs well-structured policy networks consisting of efficiently connected key actors in policy implementation. A database search revealed significantly less progress in implementing the building energy and carbon policies in developing countries, compared with developed countries. Previous literature suggested Policy Network Analysis (PNA) as a powerful tool to assess current policy level actor coalitions, determine structural holes in stakeholder integration and decide on future policy improvements. Subsequently, a database search was carried out through the “Web of Science” publications repository to identify the previous PNA approaches and to identify a potential way forward. Among the available methods, Social Network Analysis (SNA) was identified as the most suitable and frequently used method which provides extensive analytical capabilities for policy network visualization and analysis. The preliminary findings lead to the novel SNA model that is proposed to map and assess required building energy and carbon policy networks which integrate both policy actors and constraints. This proposed model can be effectively utilized to identify the significance, centrality and relational structures of policy actors and policy constraints. This paper will benefit future researchers and relevant policy makers by providing an effective platform on which to further develop more effective energy and carbon policies for the building sector by strengthening stakeholder collaboration and integration.

1. Introduction
Buildings worldwide collectively consume over one third of total energy produced and account for about one third of global greenhouse gas emissions [1]. The lowest rate of building energy efficiency improvements in the past decade was recorded in 2018 [2]. Currently, there is a rapid growth in the total building floor area globally. Yet, more than 3 billion m², the majority being from the developing countries were built in 2018 with neither governing/oversight policies, nor mandatory energy and carbon performance requirements [3,4]. This critical situation is symptomatic of very slow energy and carbon policy progress, demonstrating that the evolution of building energy and carbon policies and procedures in particular is not keeping up with rapid growth especially in developing countries [3]. Furthermore, researchers and primary energy and carbon databases also emphasize that the rapid
increase of energy demand and carbon emissions from the building construction and building stock in developing countries as a major issue which should be addressed promptly by the relevant policy making authorities [4,5,6].

To be in line with the global climate change targets, all countries should focus on implementing mandatory building energy and carbon regulations. Further, high-performance, low carbon intensive and energy efficient new construction needs to increase from the current level of 250 million m$^2$ per year up to 4 billion m$^2$, and energy efficiency renovation of existing building stock needs to achieve at least 30%-50% improvement in energy intensity through well-defined energy and carbon policies in emerging economies[3].

Nevertheless, there are a number of socio-technical constraints for the effective uptake in building energy and carbon policies in developing countries mostly due to the unstable economic situation, regulatory changes and poor technological performance levels [7]. Therefore, the influential parties should work in an integrative manner to overcome these constraints and establish proper policies. Efficient policy development and application primarily depends on the collaborative commitment and integrated vision of all the relevant regulatory bodies and other relevant influential stakeholders at macro level and micro level [8,9]. Yet, these regulatory bodies and policy actors are not well integrated and not focusing on collaborative building energy and carbon policy targets in most of the emerging economies [10]. Policy Network Analysis (PNA), was identified as an effective mechanism to map and assess the level of integration of diversified policy actors in a particular policy arena [11]. A number of policy related research studies related to environmental studies, ecology, law and public administration have utilized PNA techniques [12,13]. Social Network Analysis (SNA) was the most popular analysis tool among the scholars in PNA arena. SNA provides extensive policy network visualization and analysis capabilities to identify how the policy actors are integrated, who are the dominant stakeholders, what are the connectivity gaps, etc. Further, the quantitative network measures like centrality, density, cluster analysis and brokerage potentials analysis provide effective metrics and measures to identify policy actor attributes and policy network level attributes in an informed manner.

Considering the current situation of the energy and carbon policy progress in developing countries, it is important to analyse the current policy network structures of these countries, identify the structural holes and initiate strategies to enhance the policy actor integration focusing on strengthening and enhancing the building energy and carbon policies [14,15,16]. Hence, the aim of this paper is to propose a SNA based building energy and carbon policy network analysis model to help to enhance and reinforce existing policy network structures in developing countries. The primary goals of this network visualization and analysis model are to identify current gaps in policy actor collaborations in addressing complex socio-technical constraints and to create an effective platform to establish efficient building energy and carbon policy networks to overcome the prevailing policy constraints.

Accordingly, previous literature, building energy policy information databases and “Web of Science” electronic publication database were utilized as the data collection sources to achieve the following objectives that contribute to the specified aim of this paper: (1) To identify the status quo of building energy and carbon policies in developing countries, (2) To identify relevant policy network analysis methods and related SNA applications, (3) To propose a novel SNA model to analyse building energy and carbon policy networks in developing countries.

2. Building energy and carbon policies in developing countries
A majority of the developed nations have well-regulated building energy and carbon policies and procedures in place. But, most of the developing countries mainly focus on economic prosperity and the development of sociological aspects, thereby de-prioritizing and compromising the opportunities to pursue sustainability and to battle climate change [14,16]. Nevertheless, the contribution of emerging economies is highly important to battle climate change as these countries represent more than 74% of global population and currently experience a rapid growth in terms of industrialization and new building construction [7,16]. The rapidly growing building stock of developing countries are largely not regulated in terms of energy usage and carbon emissions and this leads to higher emissions of carbon and
significant negative effects on the environment [3, 14]. To comparatively identify the current commitments of developing countries vs. developed countries towards implementing regulatory measures for building energy and carbon sector, the authors of the present study compiled a list of data for a set of developing and developed countries by searching through building energy information databases [4,5]. First 5 countries in the table are identified as developed countries and the others are identified as developing countries by referring to United Nations organization classification on World Economics Situation and Prospects (WESP). Table 1 presents this data-set in a comparative manner.

Table 1: A comparative analysis of building energy and carbon policies at the end of 2018

| Country       | Energy codes and standards - new buildings | Compliance | Energy codes and standards - renovated buildings | Building energy information |
|---------------|------------------------------------------|------------|-----------------------------------------------|-----------------------------|
|               | Available                                 | Available  | Available                                     | Available                   |
| Sweden        |                                          |            |                                               |                             |
| Canada        |                                          |            |                                               |                             |
| Japan         |                                          |            |                                               |                             |
| Australia     |                                          |            |                                               |                             |
| UK            |                                          |            |                                               |                             |
| India         |                                          |            |                                               |                             |
| Sri Lanka     |                                          |            |                                               |                             |
| Bangladesh    |                                          |            |                                               |                             |
| Nigeria       |                                          |            |                                               |                             |
| Thailand      |                                          |            |                                               |                             |
| Paraguay      |                                          |            |                                               |                             |
| Cambodia      |                                          |            |                                               |                             |
| Myanmar       |                                          |            |                                               |                             |
| Argentina     |                                          |            |                                               |                             |
| Ghana         |                                          |            |                                               |                             |
| Yemen         |                                          |            |                                               |                             |

The above table reflects the slower progress in building energy and carbon related policy implementation in developing countries when compared with developed countries. As examples, United Kingdom has implemented all the 15 tested indicators while Australia and Sweden have implemented 12 and 11 indicators at the end of 2018. This shows the greater commitment in implementing building energy and carbon policies in developed countries. Considering the developing countries, India (4 initiatives), Sri Lanka (3 initiatives), Argentina (3 initiatives), Myanmar (3 initiatives) and Thailand (2 initiatives) showed a little progress by implementing some policy initiatives towards regulating the building energy use and related carbon emissions. Nevertheless, all the other developing countries in the above sample, have not implemented any of the initiatives in the list. Further, Liu et al.[7] and Khosla et al. [14] emphasized that most of the developing countries face difficulties in implementing proper building energy and carbon policies due to the constraints like lack of consistent building energy data, limited capacity in accessibility for technological advancements, financial constraints, political uncertainty, high rates of corruption and low institutional quality. Even though there are certain
commitments in developing countries like implementing voluntary energy codes and energy labelling, there is still a long way to go in addressing building energy and carbon policy issues. Therefore, prompt attention should be drawn towards developing and implementing proper energy and carbon policies and procedures in developing countries.

3. Policy Network Analysis (PNA)

Policies certainly arise through the focused inter-connections among different policy stakeholders. This connectivity can be emphasized through network structures to effectively visualize and analyse the interaction patterns of policy actors in a particular policy arena [17]. Actors that coalesce around a specific policy or policy approach constitute a ‘policy network’ [18]. The concept of policy networks is important in classifying and positioning policy actors with regard to agenda setting or framing policy, with respect to the degree of authority they hold [16]. PNA is a method used to explore the policy procedures, policy structures and policy outcomes through concentrating on the relational structures and collaborations among policy actors [18]. Accordingly, the scholars visualize, analyse and quantify the policy actor relationships from different channels. Statistical network analysis measures can be effectively utilized to explore the different roles of actors, to identify power and significance / centrality of actors within the network, to examine how the different actor clusters interact and engage with other clusters and to identify how the actors are positioned in critical paths in the network [19,20].

Policy actors are not only those directly involved in the primary policy arena, but include those from multiple policy related influential sectors [21]. Actors in policy networks negotiate and act to exert power over each other and other policy actors, thus playing different roles in formulating and implementing policy in which they have a stake [22]. All the policy actors need to commit on their specific roles and responsibilities as a member in an interconnected and interdependent network, to initiate, formulate and implement effective policies [16].

There is a wide spread range of actors involved in the policy arena of building energy and carbon management. Even though their stakes are different, all these parties should have collective, hence collaborative commitments towards implementing efficient policy initiatives. For instance, Pan [23] identified the diversified actors who have an influencing power over the building energy and carbon sector and categorized them in to four sections: Demand (public, occupants, clients, investors, buyers), Supply (developers, advisors, contractors, facility managers, manufacturers, energy producers and suppliers), Institution (financiers, bankers, universities, professional bodies) and Regulation (government, its departments and agencies). Further, Evans and Martinez [24] identified the actors under the categories of government sector, utilities sector, private sector, industry associations and research institutions. WBCSD [25] categorized the actors in to government and local authorities, capital providers, developers, agents, owners, users, supplies and researchers.

Policy actors and their roles are dynamic in nature and mostly influenced by the actions of other actors in the arena. Hence, it is important to examine beyond the apparent picture of stakeholders, their roles and responsibilities [26]. Stakeholder categorization does not necessarily emphasize a clear picture about the significance of their role in a particular policy arena. For this purpose, there are several stakeholder power and significance analysis methods like power and interest matrix, salience model, and direction of influence of stakeholders [27]. Identifying the level of significance of policy actors, is important for the effective establishment of policy networks.

4. Applications of Policy Network Analysis (PNA) in previous research

A database search was employed to identify the previous journal publications related to PNA by adapting a methodical process proposed by Hu et al. [28] which emphasizes the key steps of assessing the publications. Consequently, a keywords search was employed through the “Topic Search” function of “Web of Science” database, using the phrase “Policy Network Analysis”, which resulted in 45 publications from 1999 to 2018. Subsequently, the list of publications retrieved through the database search was forwarded to “VOS viewer” bibliometric analysis software platform to construct the keyword co-occurrence network (refer Figure 1(a)) to identify the significant research focuses related to PNA.
Node sizes of the network represent the frequency of occurrences of keywords and line weightages are proportionate to the frequency of co-occurrences between the keywords. Further, the pie chart in Figure 1(b) shows the frequencies of appearance of each keyword. The results testify that PNA approaches were mainly used in climate change and governance related research. Further, it is noteworthy that SNA appeared as the most popular tool to analyse policy networks in previous publications.

Further analysis of the accessed papers revealed that PNA concepts have been widely utilized in the sectors like environmental studies, ecology, law and governance and public administration studies. It is notable that a majority of PNA related studies were done in the European region. Further, the authors identified different policy network analysis methods like Exponential Random Graph Models (ERGM), Virtual Policy Networks (VPN), Agent Based Modelling (ABM), Rapid Policy Network Mapping (RPNM) matrix, Ward’s clustering method and Power dependency theory in previous studies. Nevertheless, SNA appeared as the most popular and suitable method for PNA (SNA was applied in 18 papers out of 45). Subsequently, the authors of this study specifically selected the papers with SNA approaches to further analyse the applications.

4.1 SNA as the most suitable PNA method
A social network structure contains nodes (vertices/actors) to characterise entities and ties to denote the relationships between nodes. This network establishment consists of identifying significant stakeholders or entities and establishing relationships focusing on anticipated goals [29]. PNA mainly builds on quantitative SNA techniques. There are three stages of network analysis: (1) investigating the overall network structural features, (2) investigating the features and characteristics of actor clusters and sub networks through group level network measures, and (3) investigating the roles and positions of specific actors in a network through node level network measures [30,31]. Network level measures (cohesion, density, centralization) are mainly useful to comparatively analyse different policy network structures in a policy arena and actor level measures (betweenness centrality, degree centrality, etc..) can be effectively utilized to investigate the characteristics of specific actors in a policy domain [31].

Subsequently, the authors of the present study identified 18 papers which have utilized SNA theories for PNA. A careful examination of these papers revealed that all the networks were one-mode networks which the connections were interpreted as memberships in organizations, financial connections, information exchange pathways, organizational affiliations and web links. Further, the identified network structures can be categorized in to 3 social network structures: (1) Networks connecting significant policy level stakeholders, (2) Networks to emphasize the organizational / Institutional affiliations and (3) Networks to emphasize the online links between web-based policy level stakeholder communities. All the reviewed PNA studies have mapped and analysed the connectivity pattern of different actors in a policy arena. None of the PNA studies have tried to map and assess the linkage between stakeholders / organizations and corresponding relevant tasks/ responsibilities or the influencing power of policy actors over corresponding tasks, responsibilities or constraints.
5. Proposed SNA model for building energy and carbon PNA

Policy networks in the arena of sustainability/energy/climate change action planning have primarily focused on a broad general representation of the top level policy actor networks and the previous studies do not provide a clear picture of the policy actor relationships focusing a common sustainability initiative or a common goal [10,16]. In the complex arena of sustainability, there are diversified policy actors having different priorities and most of the stakeholders do not have a clear idea about their responsibilities and tasks in policy formation and implementation [14]. The literature review and the facts that were collected and compiled through energy information databases, established the requirement of efficient building energy and carbon policy networks to overcome the constraints and strengthen the existing building energy and carbon policy structures in developing countries. Yet, the authors did not come across any previous research attempts focusing the PNA of building energy and carbon sector. Subsequently, the focused review of existing publications exhibited an increasing demand in SNA applications for PNA related studies. Further, most of the studies overlook the general policy actor relationships and interdependencies through one-mode networks without considering the engagement and commitment of policy actors for complex policy initiatives or constraints due to the less-availability of suitable methodological approaches and difficulties associated with analysing such complex networks. Considering this, the authors of the present study present a logical conceptual model as a basis for a potential future research direction to visualize and analyze building energy and carbon policy networks by considering policy actor engagement to overcome the energy and carbon policy constraints in developing countries.

![Figure 2: Proposed SNA model for building energy and carbon PNA](image)

Significantly, this model presents a two-mode network approach with meaningful one-mode conversion and analysis pathways. Steps 1 and 2 identify the policy actors and policy constraints (since this is a proposed model, the actors are identified as A1 to A5 and the policy constraints are identified...
as C1 to C6). Steps 3 and 4 identify the significance of policy actors and categorize them in to different sectors (according to a classification method mentioned in section 3). Step 5 categorizes the energy and carbon policy constraints (e.g. PESTEL method). The two-mode social network in step 6 (actor-constraint) effectively maps and assesses the influencing power of each actor for overcoming the identified constraints. Subsequently, the policy actor network in step 7 is derived from analysing the co-affiliations with constraints (two-mode to one-mode projection techniques in SNA). Then, the final PNA model is derived in the step 8 which will provide the means to determine policy actor attributes through SNA quantitative measures as described in the proposed model.

6. Conclusions

The review of existing literature and building energy information databases revealed a significant gap of building energy and carbon policy progress between the developed countries and developing countries. The current status of developing nations is way behind and needs prompt attention to establish effective policy initiatives as the building stock of these countries is increasing rapidly without proper regulations to control the energy usage and carbon emissions, which in turn is a significant contributor to global climate change. Effective policy networks consisting of well integrated policy actors, were identified as a major driving factor for the effective policy implementation. PNA initiates the policy process by analysing the existing structures and providing a baseline to develop and further strengthen the collaboration and thereby, the effective implementation of building energy and carbon policies. The bibliometric analysis also emphasized the applications and suitability of PNA mainly for the areas like climate change related studies, ecology, governance and public administration. Notably, through the review, SNA appeared as the most frequently used and suitable method for PNA. Considering the timely requirement and the capabilities of SNA, the authors of the present study proposed a novel SNA model to visualize and analyse building energy and carbon policy networks structures in developing countries. The network analysis outcomes will provide a detailed understanding on policy actor relational attributes, their influencing power over policy constraints and required improvements in policy actor integration. However, the proposed model is yet to be validated in the context of a developing country, so this will be addressed in a future exercise. The findings of this paper benefit the researchers and relevant policy makers in this field by emphasizing the timely requirement of strengthening building energy and carbon policy network structures in developing countries and also by providing an effective PNA model to base upon and analyse the building energy and carbon policy structures.

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