

Preliminary Literature Review on the Roles of Smart City Technologies for Energy Policy Making in a Policy Cycle

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ABSTRACT

To examine the development of smart city technologies to support energy policy development for carbon neutrality, a preliminary literature review was performed to categorize literature of smart city technologies based on their relevance to various stages of policy cycles of energy policies. The study was conducted by Sub-keyword Synonym Searching with keywords of smart city technologies between 2016 and 2020 and stages of policy cycles. The results showed that hot topics in smart city technologies such as circular economy, big data, circular economy, energy water nexus and microgrids are well investigated, but there was a lack of smart city technologies to support the agenda-setting process of energy policy development and a lack of development in smart city technologies directly related to policies such as smart building and smart city framework.

Keywords: Smart Energy, Smart City, Policy Making, Smart Tool, Smart Government

1. INTRODUCTION

With the carbon neutrality goals of multiple governments set between 2040 and 2060 [1] and building energy consumption accounting for 39% of global carbon emission [2], governments should speed up not only the development of energy use reduction technologies but also energy policy development and deployment to meet these targets.

One way to speed up energy policy making was to utilize the smart city tools and solutions created by the recent emerging technologies. Different information and communication technology (ICT)-based smart city tools and solutions were created to support energy policy

development in energy generation, distribution and consumption [3], [4]. Frameworks and technologies for policy making with open data and big data were also being created to support policy development [5], [6]. The development not only speeded up policy implementation, it also speeded up policy appraisal and other policy-making processes, allowing quicker policy actions to achieve the carbon neutrality targets.

Despite the development of the smart city technologies, not much literature review was done on how smart city technologies affected energy policies with few exceptional literature reviews on the effects of advanced modeling and big data techniques [6]–[8]. The effects of other emerging smart city technologies on energy policies were not well known, bringing difficulties to assess the comprehensiveness of support by smart city technologies to energy policies in the world, particularly on the four stage of policy development as represented by the policy cycle shown in Fig. 1 [9].

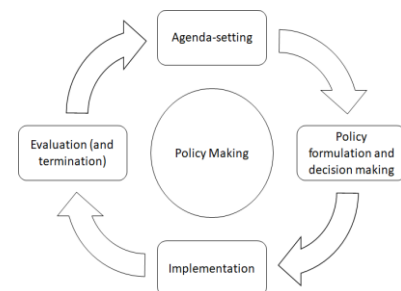


Fig. 1. Flow chart of a policy cycle

Policy cycle was comprised of 4 steps – agenda-setting, policy formulation and decision making, implementation, and evaluation (and termination). It was a cycle to show how policies were updated constantly or were terminated when deemed inappropriate. Agenda-setting was the recognition and

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selection of problems for solutions at the policy level. Policy formulation and decision making was the process to define policy objectives and to make policy decisions based on available alternatives. Implementation involved the specification of policy details and rules and the allocation of resources. Evaluation (and termination) was the appraisal of policies for potential policy re-design or policy termination.

To examine how smart city technologies supported each stage of energy policy development in Fig. 1, this paper described a preliminary literature review on smart city technologies, policy cycles and energy policies. The literature found was categorized by keywords representing emerging smart city technologies and policy cycle stages. Statistics was carried out to examine how well smart city technologies supported each stage of policy cycles of energy policies. Conclusions were made based on the statistics to suggest how energy policy development could be further supported.

2. RESEARCH METHOD

The research method of the literature review was summarized in Fig. 2.

2.1 Identification of keywords in a policy making process

The keywords to represent each stage of a policy making process were identified based on the policy cycle description in Fig. 1.

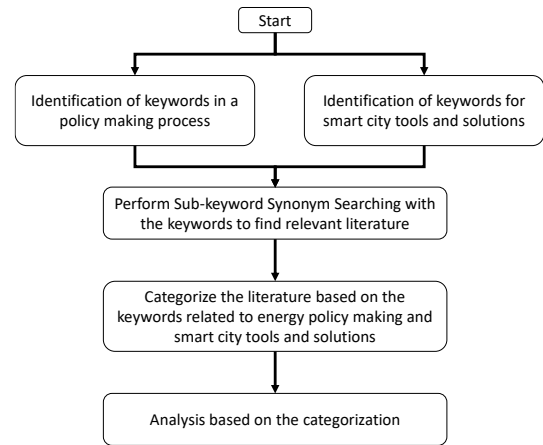


Fig. 2. Flow chart of the research method

2.2 Material and methods Identification of keywords for smart city tools and solutions

To have a list of representative keywords of smart city tools and functions based on emerging technologies, this study uses the technologies listed in Hype Cycle for Smart City Technologies and Solutions from 2016 to 2020 [10]–[14].

2.3 Use of Sub-keyword Synonym Searching algorithm to find relevant literature

Sub-keyword Synonym Searching (SSS) was a systematic method to find literature based on combinations of keywords [15]. The method started with

Tbl. 1. Search criteria of SSS

Parameter	Values
Sub-keyword list 1	“agenda”, “agenda-setting”, “formulation”, “decision making”, “implementation”, “evaluation” and “termination”
Sub-keyword list 2	“5G”, “Artificial General Intelligence”, “Autonomous Driving Level 5”, “Big Data”, “Blockchain”, “Blockchain Business Models”, “Blockchain in Government”, “Building Controls and Management”, “Building Information Modeling”, “Car-Sharing Services”, “Chatbots”, “Circular Economy”, “Citizen Twin”, “City Operations Center”, “Civic and Community Development”, “Combined Heat and Power”, “Connected Home”, “Consumer Energy Storage”, “Customer Gateways”, “Data Exchange”, “Data for Good”, “Data Marketplace”, “Digital Ethics”, “Digital Security”, “Digital Twins of Government”, “Distributed Generation”, “Energy Water Nexus”, “Greenfield Smart City Framework”, “Health Information Exchange”, “Intelligent Building Automation Systems”, “Intelligent Lamppost”, “Intelligent Lighting”, “Intelligent Street Pole”, “Internet of Things”, “IoT Platform”, “IT/OT Communications”, “Licensing and Entitlement Management”, “LPWA”, “Meter Data Analytics”, “Microgrids”, “Micromobility”, “Mobile Health Monitoring”, “Mobility as a Service”, “Robotic Process Automation (RPA)”, “Smart Building”, “Smart City as a Service”, “Smart City Framework”, “Smart City Regional Governance”, “Smart City Transportation Strategy”, “Smart Lighting”, “Smart Monitoring for Public Infrastructures”, “Smart Parking Strategies”, “Smart Transportation”, “Sustainability and COP”, “Sustainability Consulting Services”, “Vehicle-to-Grid”, “Vehicle-to-Vehicle Communications”, “Water Management”, “Wireless Electric Vehicle Charging”
Sub-keyword 3	“energy policy”
Citation threshold	10
Year from	2016
Year to	2020

multiple lists of keywords with each list containing keywords on a similar topic. The method took one keyword from each of the lists and performed a search of literature based on the keyword combination. The search result was filtered based on the number of citations of the literature, the relevance ranking of the literature to the keywords and the publication year. The method was repeated with another combination of keywords from each of the keyword list. The iteration stopped after exhausting all possible combinations. In this study, the literature review was carried out with the search engine Google Scholar based on Tbl 1.

2.4 Literature categorization and analysis

The literature was categorized based on the representation of its keywords for the stages of the policy cycle and smart city technologies. Heat maps were made based on the total number of literature and the newest publication year of the literature in each category. The distribution was examined for the support of technologies to each stage of policy cycles of energy policies.

3. RESULTS AND DISCUSSION

The search criteria in Tbl. 1 yielded 413 keyword combinations and 2,647 publications.

3.1 Number of publications

The number of publications per keyword was calculated as shown in Fig. 3.

Fig. 3 showed that while there were similar number of publications spanning from policy formulation to policy termination, not much literature covered the policy agenda-setting process. Only less than 10% of literature was related to the agenda-setting process. Agenda-setting process was only better discussed with technologies “digital ethics”, “intelligent lamppost” and “smart city regional governance”.

Fig. 3 also showed the type of technologies that were well discussed. This included “big data”, “circular economy”, “digital ethics”, “energy water nexus” and “microgrids”. Surprisingly, despite the known relevance of “smart city framework”, “digital twins of government”, “smart building” and “smart lighting” technologies with energy policies, little was discussed. However, “Mobile health monitoring” that was irrelevant to energy policy was also ranked as an important category, illustrating that further filtering of results is also needed.

Number of literature per keyword	Stages of Policy Cycle				Grand Total
	Agenda-setting	Policy decision making & formulation	Implementation	Evaluation (and termination)	
Smart City Technologies	1	0.5	1	4.5	7
Robotic Process Automation RPA	1	1.5	3	3.5	9
Micromobility	2	5.5	2	3.5	13
IT/OT Communications	1	7.5	0	7	15.5
Vehicle-to-Vehicle Communications	6	5.5	3	2	15.5
Health Information Exchange	0	7	5	6	18
Water Management	1	4.5	2	11.5	19
Intelligent Street Pole	0	12	2	5	19
Smart City as a Service	2	10.5	2	5.5	20
Blockchain in Government	1	7	5	7	20
Smart City Transportation Strategy	1	4	9	6.5	20.5
Blockchain	1	5	11	3.5	20.5
Smart City Framework	0	9	6	6	21
Data Exchange	5	6	5	5	21
Greenfield Smart City Framework	1	8	5	7.5	21.5
Citizen Twin	8	3.5	2	8	21.5
Digital Twins of Government	0	9	7	5.5	21.5
Smart Building	7	8.5	4	3	22.5
Smart Lighting	8	7	2	6	23
Chatbots	10	6.5	2	5	23.5
Intelligent Lamppost	3	12	3	6	24
Mobility as a Service	2	5.5	8	9	24.5
Connected Home	0	6.5	5	14	25.5
Autonomous Driving Level 5	5	9.5	4	7	25.5
Car-Sharing Services	0	4	4	9	26
Smart Monitoring for Public Infrastructures	3	7.5	6	10.5	27
Digital Security	0	6.5	5	16	27.5
Consumer Energy Storage	9	10	2	6.5	27.5
Licensing and Entitlement Management	6	5	4	13	28
Blockchain Business Models	2	6.5	5	14.5	28
IoT Platform	8	9	12	7.5	28.5
LPWA	5	12	3	8.5	28.5
Smart Parking Strategies	4	10.5	6	8.5	29
Intelligent Building Automation Systems	4	4.5	7	13.5	29
Intelligent Lighting	8	11.5	2	8	29.5
Meter Data Analytics	6	10.5	8	5	29.5
Smart Transportation	7	9	6	7.5	29.5
Sustainability and COP	1	7.5	11	12	31.5
5G	1	12	9	9.5	31.5
City Operations Center	13	11	5	3.5	32.5
Smart City Regional Governance	9	16	7	33	33
Data Marketplace	8	12	4	9	33
Distributed Generation	4	7	6	17	34
Combined Heat and Power	1	6.5	16	10.5	34
Sustainability Consulting Services	0	9.5	18	6.5	34
Vehicle-to-Grid	2	13	9	10.5	34.5
Internet of Things	2	8	11	14	35
Data for Good	2	7	19	7.5	35.5
Building Controls and Management	5	11	6	14.5	36.5
Artificial General Intelligence	7	8.5	13	8	36.5
Customer Gateways	4	7.5	20	5.5	37
Building Information Modeling	9	14.5	10	3.5	37
Mobile Health Monitoring	8	14	6	9.5	37.5
Wireless Electric Vehicle Charging	7	13.5	11	6.5	38
Civic and Community Development	11	8	11	11.5	41.5
Digital Ethics	8	11.5	12	12	43.5
Microgrids	4	12	14	14	44
Energy Water Nexus	6	10.5	15	13	44.5
Big Data	6	14.5	14	15.5	50
Circular Economy	239	496	424	496	

Fig. 3. Heat map of number of literature per keyword per category

3.2 Newest publication year

The latest publication year per category was summarized in Fig. 4.

Fig. 4 showed that most technologies were well discussed by the latest publication in 2020 with the exception of “distributed generation”. Considering that it was also in the list of Hype Cycle for Smart City Technologies and Solutions in 2014 [16] and its relevance with microgrids, it could be believed that its discussion was limited due to its development into another technology.

Fig. 4 also showed that the papers related to the agenda-setting process were older than others. While it might be caused by relevant discussion to be published earlier than their actual years to be emerging technologies, it might also be caused by its lack of study. More have to be studied using older data for a clear conclusion.

4. CONCLUSIONS

This paper described a preliminary literature review on how smart city technologies supported energy policy development. Through Sub-keyword Synonym Searching

Number of literature per keyword	Stages of Policy Cycle			
	Agenda-setting	Policy decision making & formulation	Implementation	Evaluation (and termination)
Smart City Technologies				
5G	2016	2020	2020	2020
Artificial General Intelligence	2019	2020	2019	2020
Autonomous Driving Level 5		2020	2020	2020
Big Data	2019	2020	2020	2020
Blockchain	2018	2020	2020	2020
Blockchain Business Models	2020	2020	2020	2020
Blockchain in Government	2019	2020	2019	2020
Building Controls and Management	2019	2018	2020	2019
Building Information Modeling	2019	2019	2019	2020
Car-Sharing Services	2019	2020	2020	2020
Chatbots	2020	2020	2020	2020
Circular Economy	2020	2020	2020	2020
Citizen Twin	2019	2020	2020	2020
City Operations Center	2016	2020	2019	2020
Civic and Community Development	2018	2020	2019	2020
Combined Heat and Power	2018	2019	2020	2019
Connected Home	2018	2020	2018	2020
Consumer Energy Storage	2020	2020	2019	2020
Customer Gateways	2019	2020	2019	2020
Data Exchange		2020	2020	2019
Data for Good	2019	2020	2020	2019
Data Marketplace	2017	2020	2019	2020
Digital Ethics	2020	2020	2020	2020
Digital Security	2018	2020	2020	2020
Digital Twins of Government	2019	2020	2019	2020
Distributed Generation	2019	2019	2019	2018
Energy Water Nexus	2019	2020	2020	2020
Greenfield Smart City Framework	2020	2020	2019	2019
Health Information Exchange	2020	2020	2020	2019
Intelligent Building Automation Systems	2019	2020	2019	2019
Intelligent Lamppost	2020	2020	2018	2020
Intelligent Lighting	2020	2019	2017	2020
Intelligent Street Pole	2016	2020	2017	2020
Internet of Things	2018	2020	2020	2020
IoT Platform	2016	2020	2020	2020
IT/OT Communications	2018	2020	2017	2020
Licensing and Entitlement Management	2020	2020	2020	2019
LPWA	2019	2020	2020	2020
Meter Data Analytics	2020	2020	2017	2020
Microgrids	2020	2020	2020	2020
Micromobility	2017	2020	2020	2020
Mobile Health Monitoring	2019	2020	2020	2019
Mobility as a Service	2016	2020	2020	2020
Robotic Process Automation RPA	2020	2019	2016	2020
Smart Building		2020	2019	2020
Smart City as a Service		2020	2019	2019
Smart City Framework	2016	2020	2020	2019
Smart City Regional Governance		2020	2020	2020
Smart City Transportation Strategy	2018	2020	2020	2020
Smart Lighting	2020	2020	2020	2019
Smart Monitoring for Public Infrastructures	2020	2020	2019	2020
Smart Parking Strategies	2019	2020	2017	2020
Smart Transportation	2019	2020	2019	2019
Sustainability and COP	2019	2020	2020	2020
Sustainability Consulting Services	2016	2020	2019	2020
Vehicle-to-Grid		2019	2020	2020
Vehicle-to-Vehicle Communications	2019	2020		2020
Water Management		2019	2019	2020
Wireless Electric Vehicle Charging	2018	2020	2020	2020

Fig. 4. Heat map of the latest publication year in each category

on literature published between 2016 and 2020, 2,647 literature was categorized into 59 smart city technologies and 4 policy cycle stages. The results showed that

1. Not much smart city technological support was studied for agenda-setting processes relative to other policy cycle stages.
2. “Big Data”, “circular economy”, “digital ethics”, “energy water nexus” and “microgrids” were smart city technologies mostly discussed with stages of policy development, while some relevant technologies on policies such as “smart city framework”, “digital twins of government”, “smart building” and “smart city” lacked discussion.

While the conclusions might be limited by the lack of filtering for topic relevance and lack of studies of the technological transitions, these conclusions suggested that more studies could be made to support agenda-setting processes for energy policies relative to other stages of policy cycles. They also suggested that some technologies that were relevant to energy policies directly such as “digital twins of government” required further support for investigation.

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