Jurnal Ekonomi Malaysia 56(1) 2022 71 - 91
http://dx.doi.org/10.17576/JEM-2022-5601-06

Decarbonizing the Global Electricity Sector through Demand-Side Management: A Systematic Critical Review of Policy Responses

(Penyahkarbonan Sektor Elektrik Global Melalui Pengurusan Sebelah Permintaan: Kajian Kritikal Sistematik Terhadap Tindak Balas Dasar)

Fathin Faizah Said
Universiti Kebangsaan Malaysia

Kazeem Alasinrin Babatunde
Alhikmah University

Nor Ghani Md Nor
Universiti Kebangsaan Malaysia

Moamin A. Mahmoud
Universiti Tenaga Nasional (UNITEN)

Rawshan Ara Begum
Universiti Kebangsaan Malaysia

ABSTRACT

This paper provides an up-to-date and comprehensive systematic literature review (SLR) of the existing research on long-term electricity decarbonization which is dominated by the global scenarios of Integrated Assessment Models. The aim is to synthesize and extend current understanding on the existing supply-side solutions and demand-side technological options despite the broader range of co-benefits and the latter's lesser risk. We achieve this by adopting a two-step systematic literature review approach to analyse and review SLR datasets consisting of 103 empirical studies conducted in Asia, Europe, and North America countries in economics and environmental economics from 1994 to 2018 and published in Web of Science and Scopus indexed journals. We find that demand-side policy studies are predominantly carried out in Asia, Europe, and North America. The US contributes more than one-quarter of the studies reviewed, most of which were published after US withdrawal from the Paris Agreement. Three types of Demand-Side Management (DSM) are identified namely energy efficiency, energy conservation, and demand response policies. The corresponding policy instruments can be categorised into six basic categories. We further found that these instruments are not always implemented for emissions reduction. In addition, energy-saving is found to be the reason for DSM implementation. The findings suggest that demand-side solutions through policies need to be fully exploited to achieve carbon emission targets from the electricity sector or energy sector in general.

Keywords: Demand-side management, electricity decarbonization policy, climate change, energy efficiency, carbon emission target
JEL: Q28, Q41, Q48, Q51, Q54

ABSTRAK

Kajian ini menyediakan kajian literatur sistematik (SLR) yang terkini dan komprehensif mengenai penyelidikan berkaitan penyahkarbonan elektrik jangka panjang yang didominasi oleh senario global dari Model Penilaian Bersepadu. Tujuannya adalah untuk mensintesis dan memperluaskan pemahaman semasa mengenai penyelesaian sebelah penawaran sedia ada dan pilihan teknologi sebelah permintaan walaupun terdapat pelbagai faedah bersama yang lebih luas dan risiko yang lebih rendah. Kami mencapai matlamat ini dengan menggunakan pendekatan dua-langkah tinjauan literatur sistematik untuk menganalisis dan mengkaji set data SLR yang terdiri daripada 103 kajian empirikal yang dijalankan di Asia, Eropah, dan negara-negara Amerika Utara dalam bidang ekonomi dan ekonomi alam sekitar dari tahun 1994 hingga 2018 dan diterbitkan dalam jurnal berindeks Web of Science dan Scopus. Kami mendapati bahawa kajian dasar sebelah permintaan kebanyakannya dijalankan di Asia, Eropah, dan Amerika Utara. AS menyumbang lebih daripada satu perempat daripada kajian yang dikaji, yang kebanyakannya diterbitkan selepas penarikan diri AS dari Perjanjian Paris. Tiga jenis Pengurusan Sebelah Permintaan (DSM) dikenalpasti iaitu kecekapan tenaga, pemuliharaan tenaga, dan dasar tindak balas permintaan. Instrumen dasar yang sepadan boleh dikategorikan kepada enam kategori asas. Kami selanjutnya mendapati bahawa instrumen ini tidak selalu *dilaksanakan untuk pengurangan pelepasan. Di samping itu, penjimatan tenaga didapati menjadi sebab pelaksanaan DSM. Penemuan menunjukkan bahawa penyelesaian sampingan permintaan melalui dasar perlu dieksploitasi sepenuhnya untuk mencapai sasaran pelepasan karbon dari sektor elektrik atau sektor tenaga secara amnya.*

Kata kunci: Pengurusan sebelah permintaan; dasar penyahkarbonan elektrik; perubahan iklim; kecekapan tenaga; sasaran pelepasan karbon

Received 23 Februari 2021; Revised 29 September 2021; Accepted 22 April 2022; Available online 28 April 2021

INTRODUCTION

That human-related activity sparks global warming is well beyond scientific misunderstanding. The electricity sector alone is responsible for more than 40% of total energy-related CO_2 emissions (IEA 2018). For the last two decades, emissions from the power industry have been growing annually at 2.3% to a value of 4.3 gigatons (Gt), accounting for about half of the total growth in CO_2 emissions within the same period (IEA 2018). In sum, the electricity sector now emits nearly 500 grams of CO2 per kilowatt-hour (g CO2/kWh) of energy generated. Consequently, electricity production's carbon intensity has been on an upward trend (Ang & Su 2016; Hinchliffe et al. 2015). Global carbon emissions from electricity generation increased in 2017 after three years of stagnancy. With the carbon emissions set to rise for the second year running, the European Union has been noticeably decarbonizing its power generation. However, much of the growth in emissions is traceable to explosive electricity demand from large developing economies such as China and India. These trends reveal that current efforts to drive CO_2 emissions down from power generation are far from enough.

Electrification in the developing world is growing concurrently with the digitalization of advanced economies and positioning electricity at the heart of sustainable economic development more than ever. According to IEA (2018), electric power is increasingly the choice of fuel for meeting companies and household's energy needs, leading to growing electricity demand. As witnessed during the 2012 large-scale blackout in eastern and northern India, electricity supply interruptions can be substantially disruptive. It is hard, if not impossible, to think of a more crucial sector to the economy than power. But the fast-growing electricity demand and its increasing coal share in the energy mix poses severe and urgent environmental concerns, given the current world population and economic growth trajectory.

The current climate literature on long-term electricity decarbonization to meet Intended Nationally Determined Contributions (INDCs) is dominated by global scenarios from Integrated Assessment Models (IAMs). It gives special attention to supply-side solutions over demand-side technological options. This dominance in the literature is possible because of IAMs' unique ability to link the following: technology portfolios, mitigation strategies, emission budgets and corresponding warming outcomes (Mundaca et al. 2018; Wilson et al. 2012). Recent studies reveal how demand-side solutions have been poorly represented in the policy discourse despite the reliance on low energy demand in deep decarbonization pathways (Rogelj et al. 2015). More so, Demand-side solutions have a full range of benefits and are associated with lesser risk compared to supply-side options: they potentially come along with co-benefits for health (von Stechow et al. 2016), living standard (Vu et al. 2018), equity (Ito & Ida 2018), security (Al-Rubaye et al. 2018), system cost (Cui & Li 2018), and pollution (Ürge-Vorsatz et al. 2016). Demand-side solutions incorporate greater flexibility into the decarbonization pathways and reduce global disaster risk (Wilson et al. 2012). To date, we do not fully understand the state of the demand-side policy measures in the context of electricity decarbonization (Mundaca et al. 2018). Recent literature advocates for more scientific research in demand-side policy evaluations (Creutzig et al. 2018; Creutzig et al. 2016).

This study systematically reviews demand-side management literature to strengthen and broaden the evidence-based demand-side policy instruments in reducing carbon emissions. We also address the research gap regarding how these policy instruments can achieve a profound electricity decarbonization goal.

DEMAND-SIDE MANAGEMENT (DSM)

Electricity DSM can be described as programs, actions, and technologies on the demand-side of electricity that seek to reduce or manage electricity consumption to either minimize the expenditure of power system or orchestrate toward achieving policy objectives such as carbon emissions reduction or demand-supply balancing (Warren 2014). From a business perspective, it will seem that a rational economic approach would be to boost demand, thereby increasing supply. This will be a reasonable business decision if there were excess supply, and revenue was the most crucial consideration in the electricity market. However, increased revenue from electric power sales does not necessarily translate into higher profit. In many situations, the least cost policy measure could justify the application of DSM solutions to be more profitable than expanding the existing power generating capacity (UNIDO 2009). Therefore, power companies might be better positioned in the industry by promoting DSM measures. From the view of cleaner production, a reduction in electricity demand due to improved energy conservation or efficiency minimizes the environmental impacts (e.g. climate change) of electricity consumption associated with a specific production level (Babatunde et al. 2021). In this regard, promoting DSM through policy instruments can help reduce the carbon intensity of the electricity sector.

A review of articles published in the last two and half decades reveals a significant dichotomy in DSM measures classification. The first set of studies categorized DSM into two distinct parts – Energy Efficiency (EE) and Demand Response (DR) (Alasseri et al. 2017; Olkkonen et al. 2017). The second strand of literature contests the idea of merging EE and Energy Conservation (EC) into one. They instead opted for EC as a new classification (Linares & Labandeira 2010; Meyabadi & Deihimi 2017). It is argued that while EE and EC undoubtedly have the same policy goal of reducing electricity consumption, they differ in approaches towards achieving it. The reason why EE, DR, and EC were chosen for this analysis has been clearly encapsulated by Boshell and Veloza (2008) as "energy efficiency, conservation, and demand responsive actions, such as load management or load shifting, are some of the energy demand reducing activities encompassed by the term Demand Side Management (DSM)." And lastly, a case has been made for on-site storage and generation as the fourth category of DSM by the last group of scholars (Warren 2018; Tronchin et al. 2018).

Despite the dichotomies, Individual DSM measure differs significantly from one another, and a few distinct classifications of the DSM can be observed. While different categories can be identified, the difference between EC, DR, and EE is more suitable for this study's aim.

ENERGY EFFICIENCY (EE) POLICIES

EE is an efficient and cost-effective means of decarbonizing the power sector, and it is believed to be repositioning itself across the globe as the *'first fuel'* (OECD/IPEEC 2016). This is a true reflection of a paradigm shift towards demand-side solutions for reducing emissions from the power sector (Wakiyama & Kuramochi 2017; Khan 2018). The traditional attention on energy saving by policymakers at the global and national level as EE's primary policy goal has sometimes led to an underestimation of the EE's full benefit (Kamal et al. 2019). According to International Energy Agency, EE can be accompanied by many benefits, such as promoting the electricity system's decarbonization, enhancing other environmental goals, and supporting strategic objectives for social and economic development (IEA 2015). Based on this study, EE policy instruments are classified into regulatory through measures such as energy efficiency standard (ESMAP 2018; Gary et al. 2013), price-based through tradable white certificate (OECD/IPEEC 2016) and price deregulation (Zhang 2015), Incentive-Based via feed-in tariff (Eyre 2013), grants (Sousa & Martins 2018; Liu 2018), tax incentive (Henriksson et al. 2014; Henriksson et al. 2012), and customer education through public enlightenment (Datta & Gulati 2014; Dulleck & Kaufmann 2004).

ENERGY CONSERVATION (EC) POLICIES

Due to the accelerated growth recorded in the last few decades, energy consumption has risen astronomically. Both Annex 1 and non-Annex 1 countries are among the top energy consumers in the world, with China as number one in terms of total primary energy consumption and Kuwait as a leading country when it is energy per capita (Fig. 1). Hence, the previously assumed infinite energy source is now depleting at an alarming rate. In response, many countries are currently reducing their carbon footprint and becoming energy independent through energy conservation measures. EC includes any efforts that result in decreased energy consumption by consuming less of an energy service (Bager & Mundaca 2017). With increasing electricity demand and the need to decarbonize the power sector, many countries have accelerated efforts toward conserving energy through dedicated policy measures (Kotchen & Moore 2008; Loi & Loo 2016). More like EE, EC policy instruments are classified into regulatory policy measure such as mandatory rationing (Honjo et al. 2018), price-based through increasing block pricing (Zhang et al. 2017), price deregulation (Adom 2016), incentive-based by weatherization Assistance Program (Zivin & Novan 2016), financial incentives (Considine & Sapci 2016), community engagement (Morris et al. 2014), voluntary-based through the green-electricity program (Kotchen & Moore 2008), and customer education via public enlightenment (Bager & Mundaca 2017).

DEMAND RESPONSE (DR) POLICIES

Demand response (DR) can be described as "*changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized*" (DOE 2006). DR involves all deliberate efforts towards modifications of the electric power consumption pattern by electricity consumers to change the level, timing of instantaneous demand, or aggregate electricity demand (Kim 2017; Kim 2016). Active engagements to improve customers' electricity consumption in response to policy incentives or price signals are fundamental objectives of DR (Kolokotsa 2016). DR offers the possibility of flexible management of electric power consumption regarding peak and off-periods and, more importantly, with balancing the load with the producible power on a real-time basis. DR policies can be divided into incentive-based DR via policy instruments such as financial incentive (Bradley et al. 2016), customer reward scheme (Vu et al. 2018), earliest-deadline-first scheduling (Bitar & Xu 2017), demand-side bidding (Adika & Wang 2014), and peak demand contract (Lima et al. 2018) as well as time-varying price mechanisms such critical peak pricing (Y. Li et al. 2018), real-time pricing (Yao et al. 2017), time of use (Cui & Li 2018), and demand-aware pricing (Hayes et al. 2017).

METHODOLOGY

For practitioners and professionals, systematic literature reviews (SLR) can solve managerial and real-life problems by providing evidence-based knowledge through research finding syntheses from a wide range of studies (Rousseau et al. 2008; Briner & Denyer 2010). For academic researchers, SLR can be used to validate models, thereby enhancing methodological improvement and accuracy along with the opportunity to identify gaps for further studies (Schanes et al. 2018; Cherp et al. 2018). In this study, a systematic literature review is carried out to characterize relevant studies regarding demand-side policy instruments and define a comparative framework to identify the current state of the art and research gap concerning the DSM role in electricity decarbonization. The most critical phase in conducting SLR is designing a protocol that clearly defines the study's main aims, exclusion and inclusion criteria, and the analysis plan (Babatunde et al. 2017). The main research questions addressed in this study are;

1. How is DSM research geographically distributed?
2. What are demand-side policy instruments being implemented across the world?
3. What demand-side policies are being built in response to carbon emissions from the power sector?
4. What types of models are being built to access the impact of demand-side policies?
5. What are the main research gaps in line with global emission reduction targets?

LITERATURE SEARCH

All research articles with demand-side policy focus and policy assessment were carried out were identified through two world-renown multidisciplinary bibliographic databases (Martín-Martín et al. 2018). There are Scopus and Web of Science (WoS), using the following search strings: "demand-side management" AND "Electricity Demand" AND (policy* OR measure* OR intervention*), ("energy efficiency" OR "energy conservation" OR "Demand response") AND "Electricity Demand" AND (policy* OR measure* OR intervention*).

A published article is included if: (1) it is a peer-reviewed research article; (2) it is on demand-side policy measure(s) in the electricity sector; and (3) an empirical model is applied to assess the policy implications from end-users perspectives. Studies related mainly to demand-side policy in another industry other than electricity, demand-side technology, elasticity were excluded. Document types such as book, book chapter, conference proceedings, and review are also excluded in favour of article type papers. No date or language restrictions are imposed except Costa and Galvis', written in Portuguese but later translated into English. The search was conducted in February 2019 to ensure that all 2018 research articles were considered.

SEARCH ENGINE AND OUTPUT

Confining the search to WoS and Scopus indicates that our review is not exhaustive and represents only a sample of demand-side policy assessment literature. At first, a total of 809 studies were retrieved. At stage two, we glanced through the titles and abstracts to choose articles based on the inclusion criteria; 134 are selected and passed through full-text reading, of which 103 research studies fulfilled the inclusion criteria. Seventy-three are from Scopus and sixty-two from WoS, of which thirty-two articles are retrievable from both databases (Fig. 2).

DATA EXTRACTION

The following information is obtained from each included research article: title, year of publication, journal, types of demand-side policies, policy categories, instruments, status and implementer, study location vis-à-vis economic status, geographical regions, end-user sectors, and modelling paradigms.

We analyze each study based on different types of DSM (i.e. energy efficiency, energy conservation and demand response) and classify them into six broad categories (regulatory, price-based, incentive-based, community-based, customer education and voluntary based policies). We further categorize each research article based on the demand-side policy instruments such as time-of-use pricing, block pricing, energy efficiency standard, feed-in tariff, financial incentive, community engagement, white certificate scheme etc. Finally, we classify each policy-oriented study on whether it is emissions reduction oriented or not.

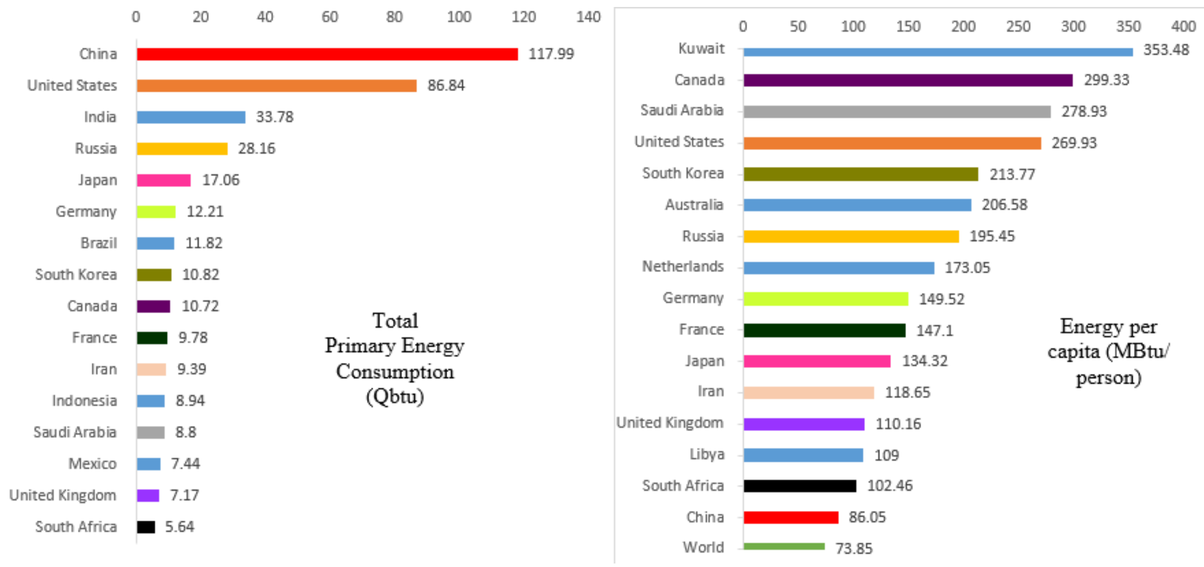

FIGURE 1. Total primary energy consumption vs energy per capita
Source: (Figure is tabulated by authors)

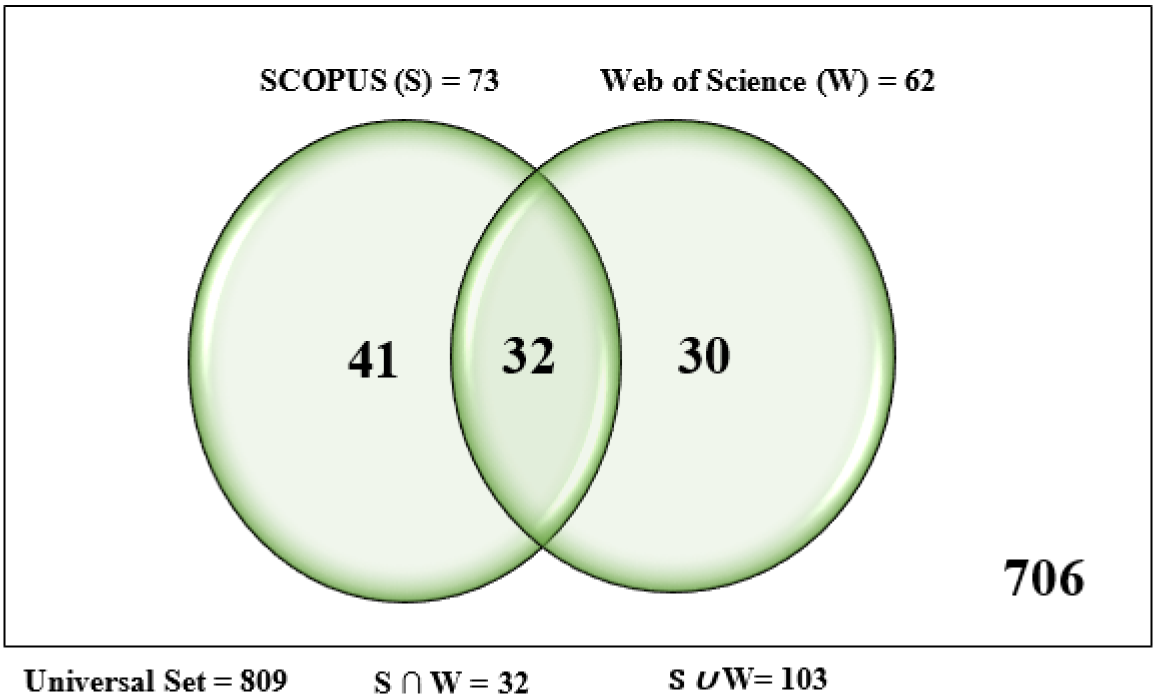

FIGURE 2. Review article by bibliographic databases
Source: (Figure is tabulated by authors)

Based on study location, each article is classified by country and geographical regions of the world to see if there is a regional pattern in the studies reviewed. Six continents classification is used: in Africa, Asia, Australia/Oceania, Europe, North America, and South America (Fig. 3). Based on the country's economic development and income level, research articles are further classified as follows: developing economies, economies in transition, and developed economies; low-income, lower middle income, upper middle income, and high-income.

Information concerning the types of methodological approaches deployed in assessing the demand-side policy instruments has been extracted from each study and assigned to the appropriate categories. The following six modelling paradigms are identified: equilibrium model, optimization model, simulation model, qualitative model, and experimental model. In addition to the methodological approaches, each article is grouped based on the targeted electricity end-user sector. It includes the residential sector, the commercial sector, and the industrial sector. It goes without pointing out that policy can be designed to cut across more than one sector; in this sense, such an article will be assigned to a category we called *crosscutting*.

Finally, over the last three years, the world has been marked by enormous ratification of the Accord de Paris (Paris Agreement) and growing energy decarbonization (Creti & Nguyen 2018). However, the United States' withdrawal from the agreement has come at a critical period of the global struggle against climate change (Nong & Siriwardana 2018). Of concern is the possibilities of bandwagon effect by other nations (M. Cooper 2018; Rhodes 2017). In this regard, the reviewed studies have been grouped into three separate periods: before Paris Agreement, the Paris Agreement year, and after Paris Agreement to find out if the agreement, along with U.S. withdrawal, has any implication on energy researches.

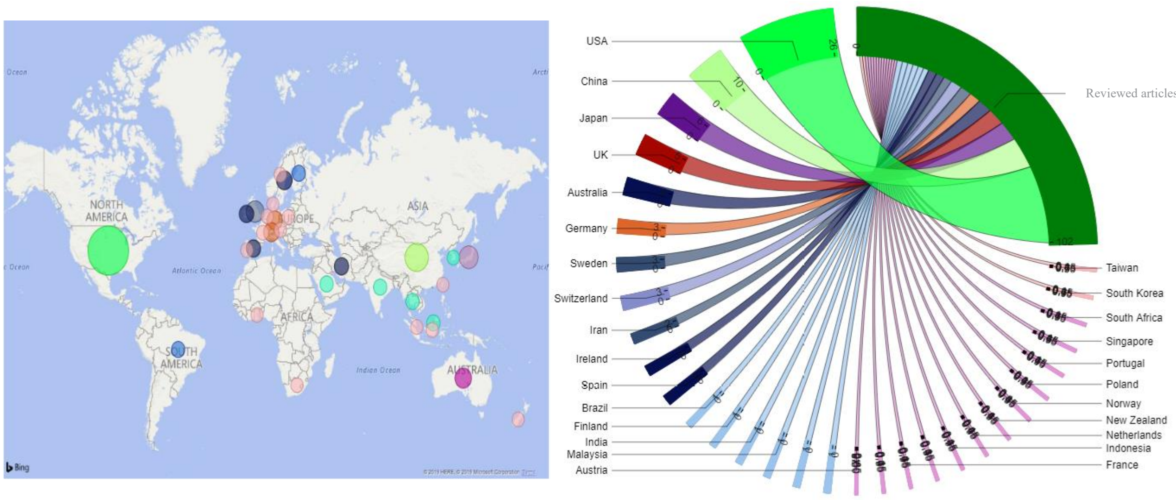

FIGURE 3. Geographical and country distribution of the reviewed articles
Source: (Figure is tabulated by authors)

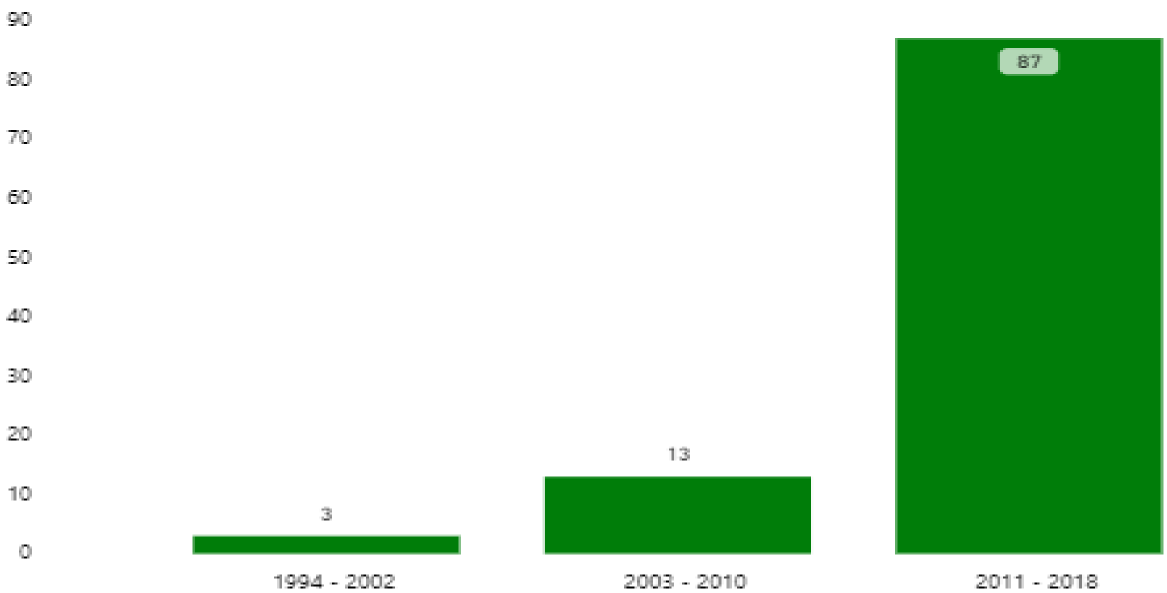

FIGURE 4. Number of articles per period
Source: (Figure is tabulated by authors)

FINDINGS

The earliest study was carried out by Swisher et al. and published in Energy Policy (Swisher et al. 1994). This followed by the work of Intarapravich in 1996 (whose research focus was on Thai electricity decarbonization via energy efficiency and conservation measures) and Waide et al. in 1997 with energy efficiency standards as their primary policy instrument. These two articles were published in Ambio and Energy & Buildings, respectively. Since then, the assessment of demand-side policy instruments has increased rapidly, with 13 articles published between 2003–2010 and 87 studies from 2011 to the end of 2018 (see Fig. 4).

AUTHOR DEMOGRAPHICS

Given the magnitude of DSM potentials across all countries, policy instruments are expected to be used to overcome its implementation challenges and achieve its broad objective. Hence, a question is asked to identify if a research study on demand-side policy assessments concentrates on one country or continent or a global phenomenon. The huge DSM potential has attracted diverse scholarly research interests from around the world. The majority of the authors are affiliated with institutions in Asia (32%), Europe (32%), and North America (26%), with a total of over 90% of the reviewed studies (Fig. 5). In comparison, the whole Africa continent and South America are undoubtedly under-represented despite their huge energy saving potentials (Schaeffer et al. 2009; Silva & Nasirov 2017; Ouedraogo 2017). The magnitude of effects and burden they could shoulder if temperatures were to rise, with the less developed regions likely to be affected the most (Oyeniran & Babatunde 2015). Our findings attest to the positive responses from world-leading CO_2 emitters, as about 87% of DSM studies with emission reduction focus were predominantly conducted in Europe, North America and Asia (Fig. 5).

Regarding DSM researches by country of affiliations, the United States was the largest source of DSM policy research destination before the Paris Agreement (PA). However, the dominance of the United States has been swept away since then (Fig. 6). The percentage of empirical studies coming from institutions within the United States, although, remained at 33% between 1994 to 2015 (the year of the 21st Conference of Parties (COP) held in Paris) has fallen to 20% within 2016–2018 (period after Paris Agreement). The empirical research from the United Kingdom and Sweden fell from 9% and 7% before PA to 4% and 2% after PA. Only scholars from Germany have not been assessing the demand-side policy measure after PA (Fig. 6).

Comparing the period before PA with the period after the agreement, an increased number of empirical DSM literature now emanates from institutions in the following countries: China, Australia, Switzerland, Iran, Brazil, Finland, Saudi Arabia, and Malaysia with less than 2% of the total reviewed articles. There is also an upward surge in research interest from academic institutions in 'other' countries (i.e. 13% before PA compared to 16% after PA), indicating an upward trend towards applying DSM, most notably concerning electricity decarbonization despite US withdrawal from PA (Fig. 6).

Fig. 7 provides information on the distribution of the studies between developed and developing countries. Despite the leadership of developed countries in terms of

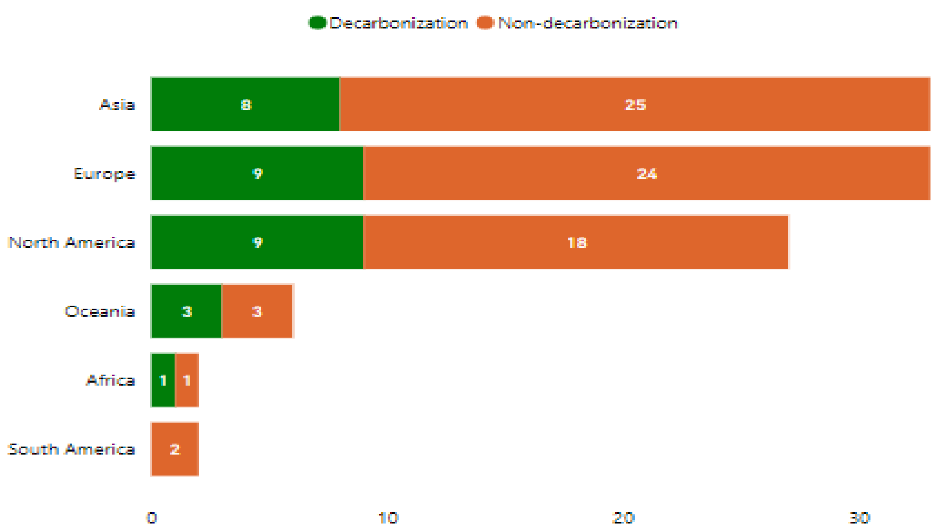

FIGURE 5. Distribution of studies by regions
Source: (Figure is tabulated by authors)

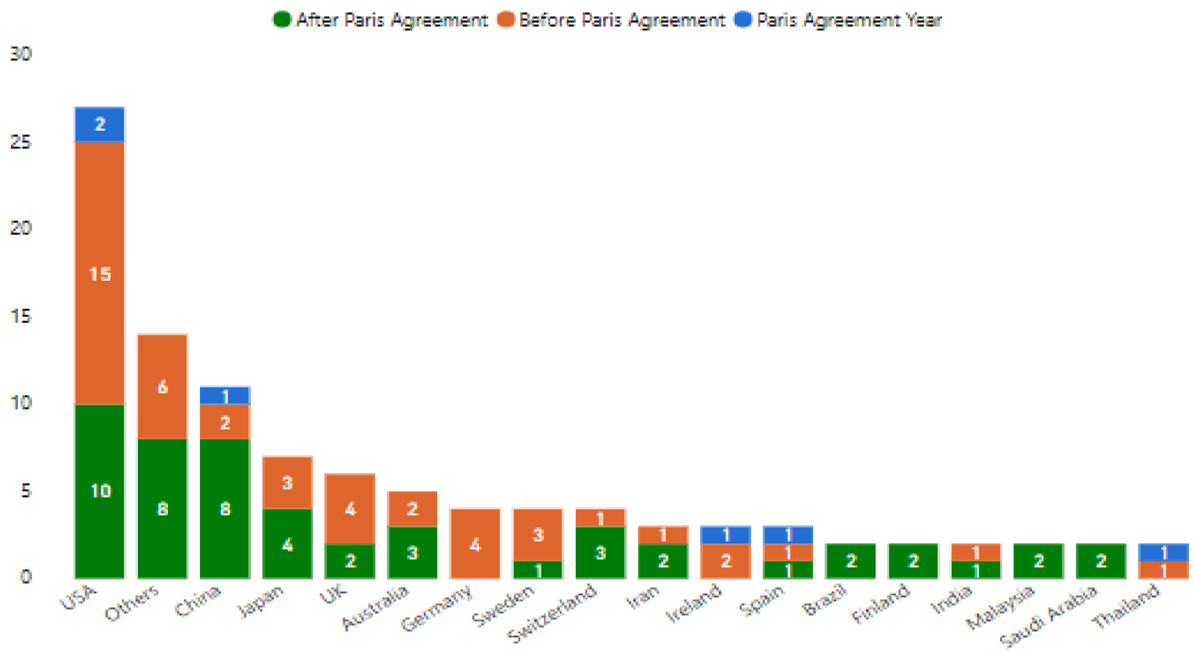

FIGURE 6. DSM studies by country before and after the Paris Agreement
Source: (Figure is tabulated by authors)

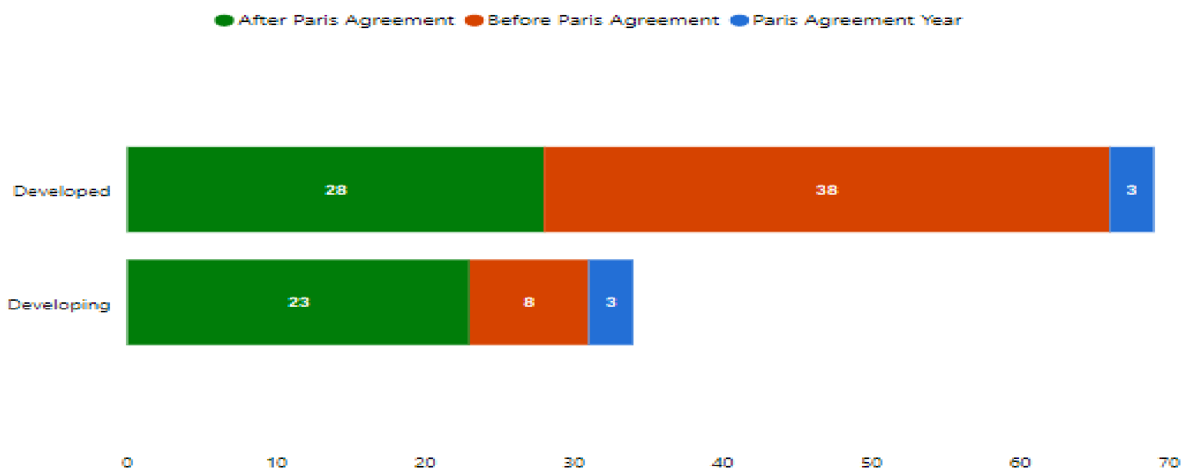

FIGURE 7. Demand-side policy publications by country's development status
Source: (Figure is tabulated by authors)

DSM research outputs with about 67% published articles within the reviewed period, developing countries have shown tremendous research improvement since PA. The proportion of published studies from developing nations increased from 17% before PA to 45% after PA, while the developed world's contributions fall from 83% before PA to 55% after PA. Meanwhile, the scientific contribution to DSM remained 50/50 contribution between developed and developing countries during the year of the agreement.

ARTICLES DISTRIBUTION BY JOURNAL

This study reviews one hundred and three research articles retrieved from thirty-nine different journal cutting across a wide range of disciplines. The largest recipient of demand-side policy research is from Energy Policy, with around 25.24% of the reviewed articles. This followed by Applied Energy (5.83%), Energy Journal (5.83%), and IEEE Transactions on Smart Grid (5.83%). The next most popular research destinations are Energy (4.85%), Energy Efficiency (4.85%), Journal of Cleaner Production (3.88%), Energy Economics (3.88%), Energy and Building (3.88%), and Energy Strategy Reviews (2.91%). This followed by journals with only two published articles: Electric Power Systems Research, Environmental and Resource Economics, IEEE Transactions on Power Systems, Journal of Process Control, and Plos One. A journal that publishes only one article is classified among Others (Fig. 8).

DEMAND-SIDE POLICY INSTRUMENTS

Three types of DSM policies (i.e. demand response, energy conservation, and energy efficiency) have been identified based on six major categories (i.e. community-based, incentive-based, price-based, regulatory, voluntary and education-based policy instruments). Fig. 9 shows twenty different policy instruments corresponding to the three types of DSM based on six policy categories. Information about the status of the policy concerning the country's economic status is provided in Fig. 10. About 77% of the reviewed articles assess existing policies, 16% propose new measures and only 7% examine piloted/trial policy, of which 85% are conducted in high-income countries, 8.7% in upper-middle economies and the remaining 6% are carried out in lower-income countries. Research contributions from developing nations improved from 24% in the proposed policy to 37% under the existing policies' assessment.

In comparison, the proportion of the research output in developed countries dropped from 76% to 63% under the proposed policy to the on-going policy. The number of empirical studies by policy instruments is provided in Table 1. More than 50% of the reviewed articles focus on demand response, 35% on energy efficiency, and the remaining 15% on energy conservation.

DEMAND RESPONSE RESEARCH

Under DR policies, nine kinds of policy instruments have been identified, of which 83% are priced-based, 15% are incentive-based, while the remaining 2% fall under 'multiple categories'. Time-of-use pricing remains the most popular policy, with about 38% of the total DR literature followed by real-time pricing at 11.5%, critical peak pricing at 9.6%, and financial incentive at 6%. Customer reward scheme, demand-aware pricing, demand-side bidding, earliest-deadline-first scheduling, and peak demand contract together account for 9.6% of the DR studies. The remaining 25% are for scientific research that considers more than one policy instrument (Table 2). 25% of the DR published works originate from the United States, followed by China and Japan with 11.5% and 9.6%, respectively. In sum, DR policies are usually initiated and implemented for purposes other than electricity emissions reduction, as 88.5% of scientific literature is centred on themes such as peak saving, energy-saving, and customer welfare, while the remaining 11.5% focus on electricity decarbonization themes.

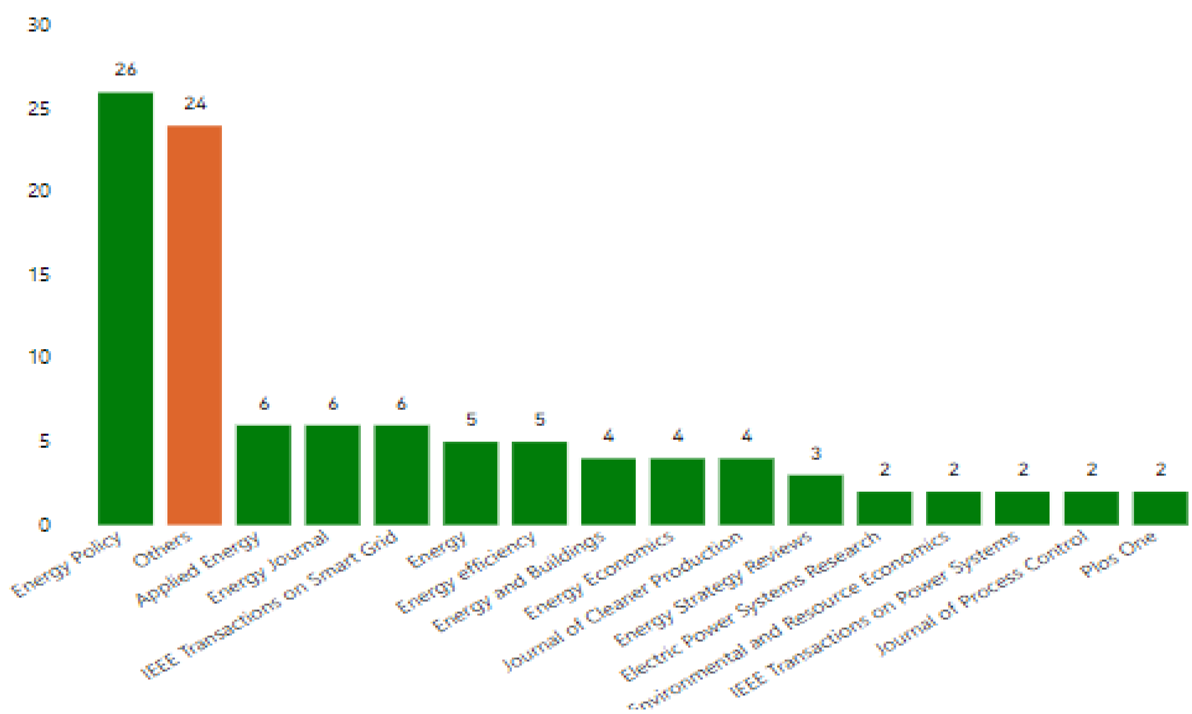

FIGURE 8. Number of research articles by journal
Source: (Figure is tabulated by authors)

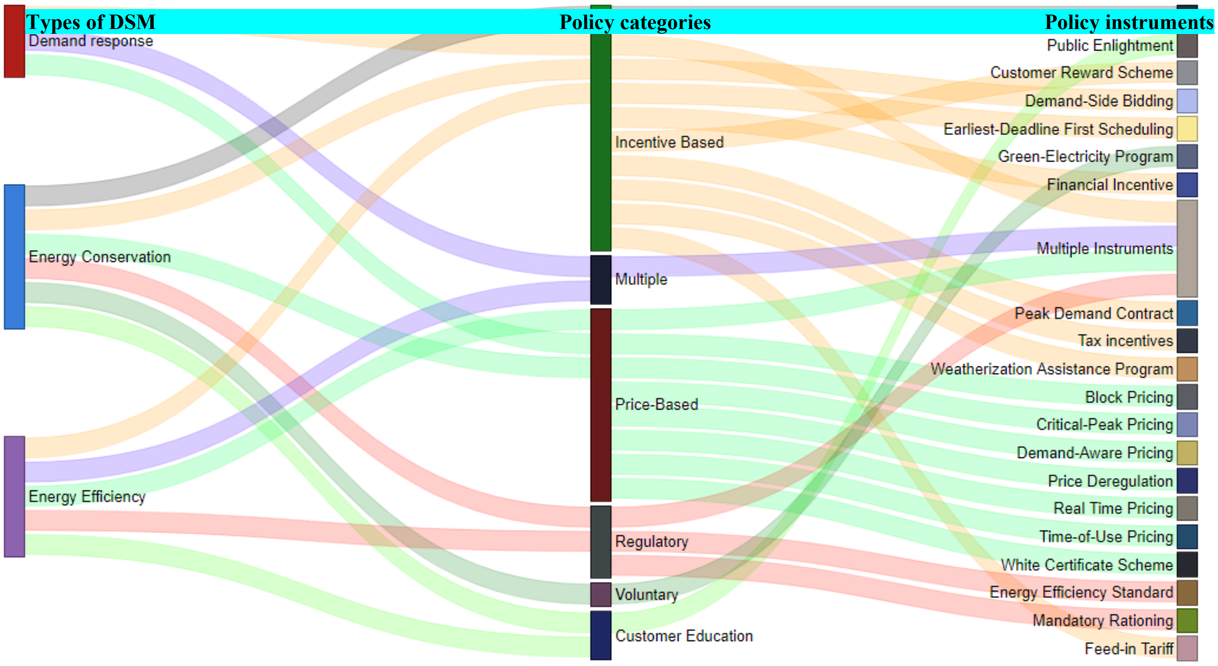

FIGURE 9. Connections between DSM policies, policy categories and instruments visualized in the Sankey diagram
Source: (Figure is tabulated by authors)

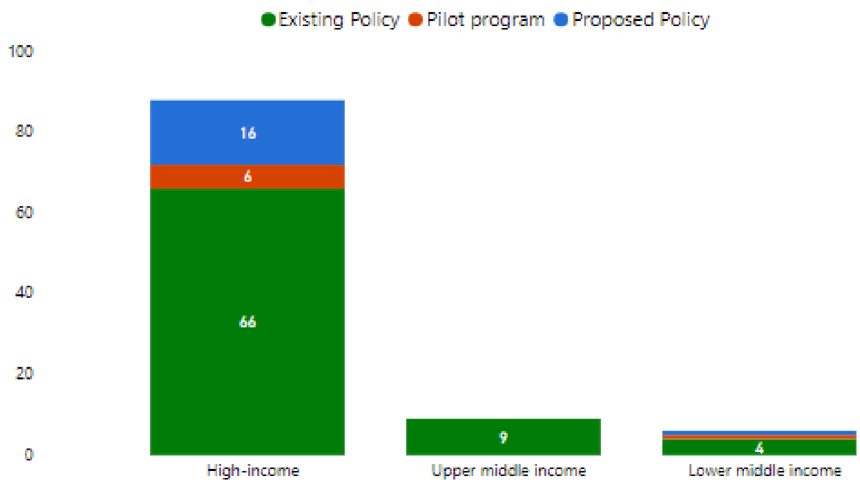

FIGURE 10. Policy status by country's economic status
Source: (Figure is tabulated by authors)

ENERGY CONSERVATION RESEARCH

Eight types of policy instruments found in EC literature cut across all six policy categories with price-based (33%) as the highest, followed by incentive-based (27%), regulatory (20%), voluntary, customer education and community-based policies all account for 20% of the studies (Table 3). The United States and China lead in deploying EC policy tools, unlike DR, EC policies are geared more towards reducing CO_2 emissions from the electricity sector, as more than 33% of the research focus on electricity decarbonization.

ENERGY EFFICIENCY RESEARCH

This review has revealed eight different types of EE policy instruments employed in the literature. Unlike both DR and EC, only four policy categories are found, with the majority of the policies being regulatory (39%), followed by incentive (19.4%), customer education (8.3%), and priced-based (8.3%). Studies with more than one policy category are classified as multiple (25%). Like DR and EC, the United States has the most extensive scientific contribution, with one-quarter of the whole EE literature reviewed. This followed by

TABLE 1. Number of policy instruments corresponding to DSM types

Demand-Side Policy Instruments	Demand response	Energy Conservation	Energy Efficiency	Total
Multiple Instruments	13	3	12	**28**
Time-of-Use Pricing	20			**20**
Energy Efficiency Standard			13	**13**
Financial Incentive	3	2	3	**8**
Real Time Pricing	6			**6**
Critical-Peak Pricing	5			**5**
Block Pricing		4		**4**
Public Enlightment		1	3	**4**
Price Deregulation		1	1	**2**
Tax incentives			2	**2**
Community Engagement		1		**1**
Customer Reward Scheme	1			**1**
Demand-Aware Pricing	1			**1**
Demand-Side Bidding	1			**1**
Earliest-Deadline First Scheduling	1			**1**
Feed-in Tariff			1	**1**
Green-Electricity Program		1		**1**
Mandatory Rationing		1		**1**
Peak Demand Contract	1			**1**
Weatherization Assistance Program		1		**1**
White Certificate Scheme			1	**1**
Total	**52**	**15**	**36**	**103**

Germany, the United Kingdom, and Sweden with 11%, 6%, and 6% contributions, respectively (table 4). More so, EE policy is mostly designed to reduce emissions from the power sector. This evidenced as 53% of EE published articles are assessed based on the policy capacity to reduce emissions from the electric power sector.

TABLE 2. Demand response policy instruments

Demand-Side Policy Instruments	Demand response
Critical-Peak Pricing	5
Customer Reward Scheme	1
Demand-Aware Pricing	1
Demand-Side Bidding	1
Earliest-Deadline First Scheduling	1
Financial Incentive	3
Multiple Instruments	13
Peak Demand Contract	1
Real Time Pricing	6
Time-of-Use Pricing	20
Total	**52**

TABLE 3. Energy conservation policy instruments

Demand-Side Policy Instruments	Energy Conservation
Block Pricing	4
Community Engagement	1
Financial Incentive	2
Green-Electricity Program	1
Mandatory Rationing	1
Multiple Instruments	3
Price Deregulation	1
Public Enlightment	1
Weatherization Assistance Program	1
Total	**15**

TABLE 4. Energy efficiency policy instruments

Demand-Side Policy Instruments	Energy Efficiency
Energy Efficiency Standard	13
Feed-in Tariff	1
Financial Incentive	3
Multiple Instruments	12
Price Deregulation	1
Public Enlightment	3
Tax incentives	2
White Certificate Scheme	1
Total	**36**

RESEARCH MODELLING PARADIGMS

Energy modelling is essential before and after designing a demand-side policy. It can be used to know the likely effectiveness and efficiency of a policy, preventing the implementation of poorly designed measures and technological uptakes. Models can also be deployed to evaluate existing policy measures if there is a need for policy adjustments, modifications, or overall turnarounds. In recent years, there has been a significant milestone in modelling development. This success has been partly motivated by the desire to address climate change.

Five types of modelling paradigms have been identified across the literature. The equilibrium model is the most widely used paradigm with about 43% of

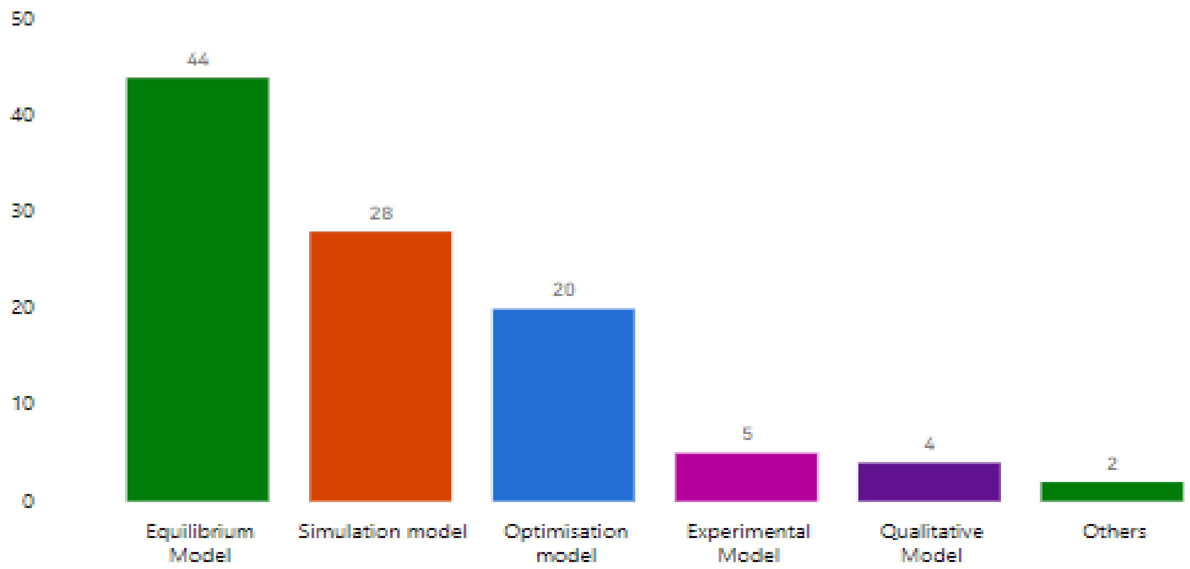

FIGURE 11. Types of DSM models
Source: (Figure is tabulated by authors)

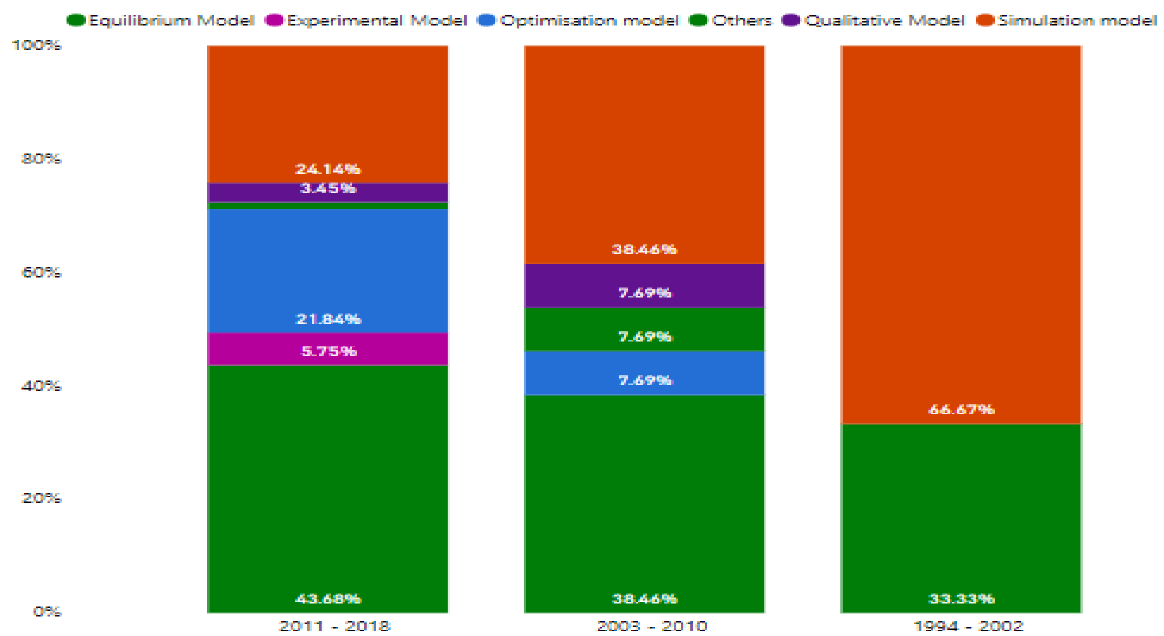

FIGURE 12. Share of DSM models
Source: (Figure is tabulated by authors

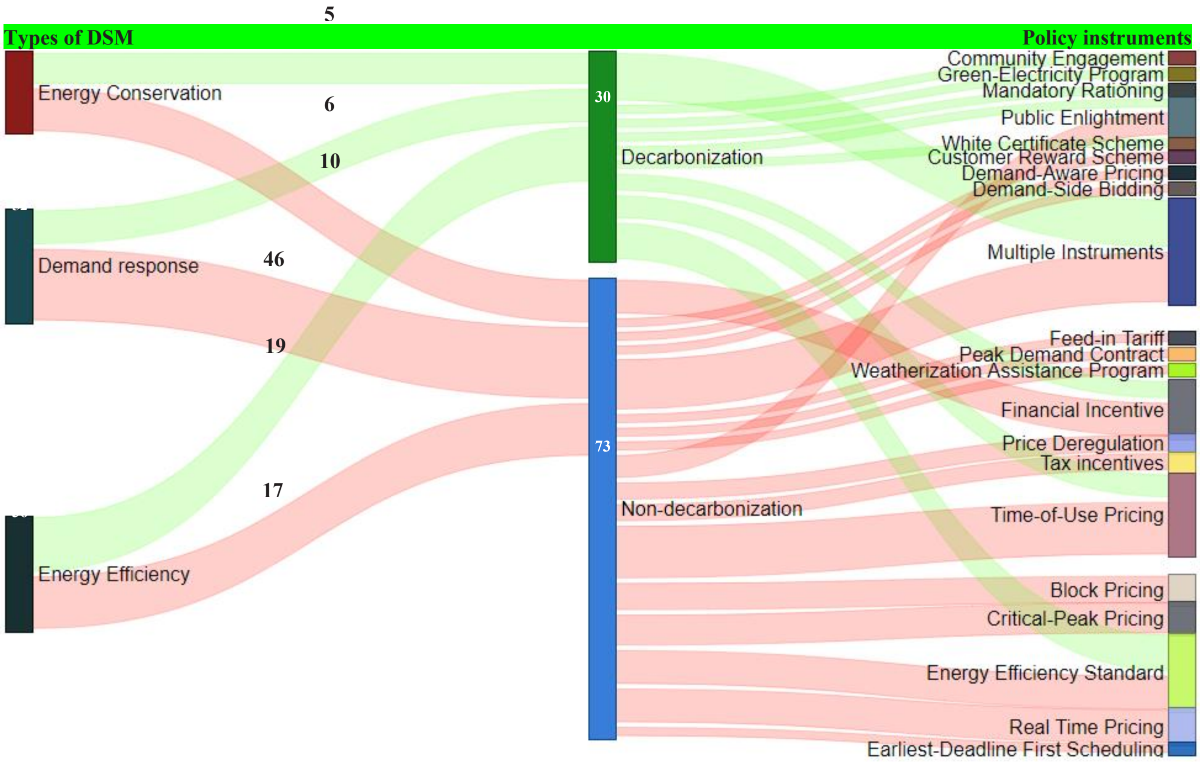

FIGURE 13. Connections between DSM policies, decarbonization and policy instruments displayed in the Sankey diagram
Source: (Figure is tabulated by authors)

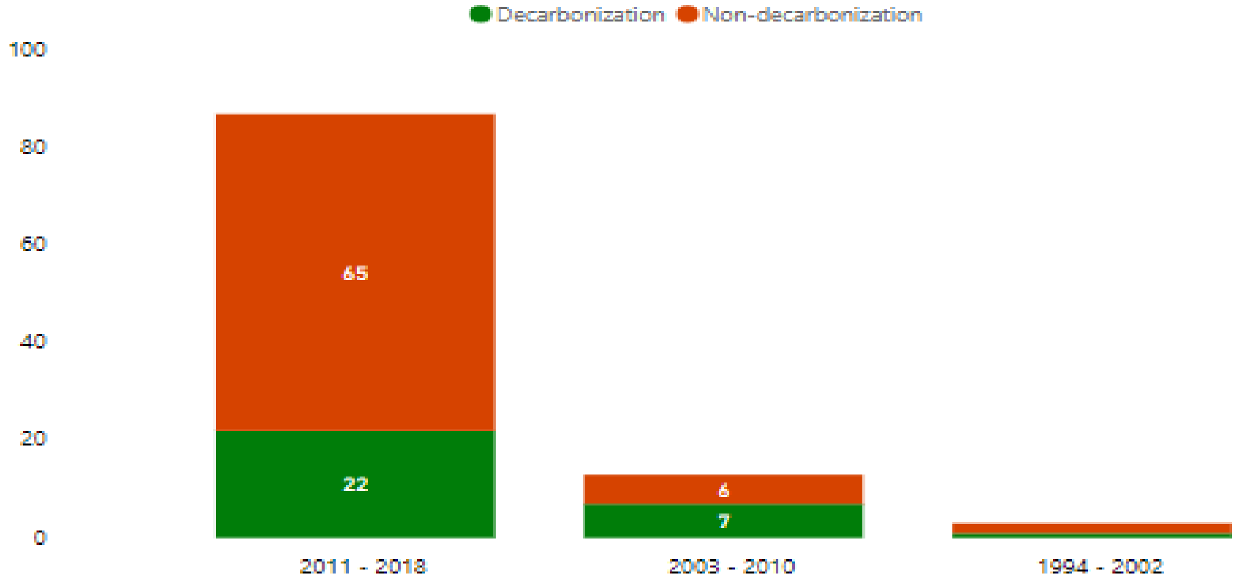

FIGURE 14. DSM studies by policy goal
Source: (Figure is tabulated by authors)

the reviewed studies, followed by the simulation model (27%), optimization model (19%), experimental model (5%), qualitative model (4%), and the remaining 2% for studies whose model are not explicitly stated (Fig. 11). As an ex-post tool, the equilibrium model application has been consistent over the study period. The proportion of studies employing the model increased from 33.33% between 1994-2002 to 53.85% between 2003-2010 and fall to 40.23% between 2011-2018. Meanwhile, empirical studies using the optimization

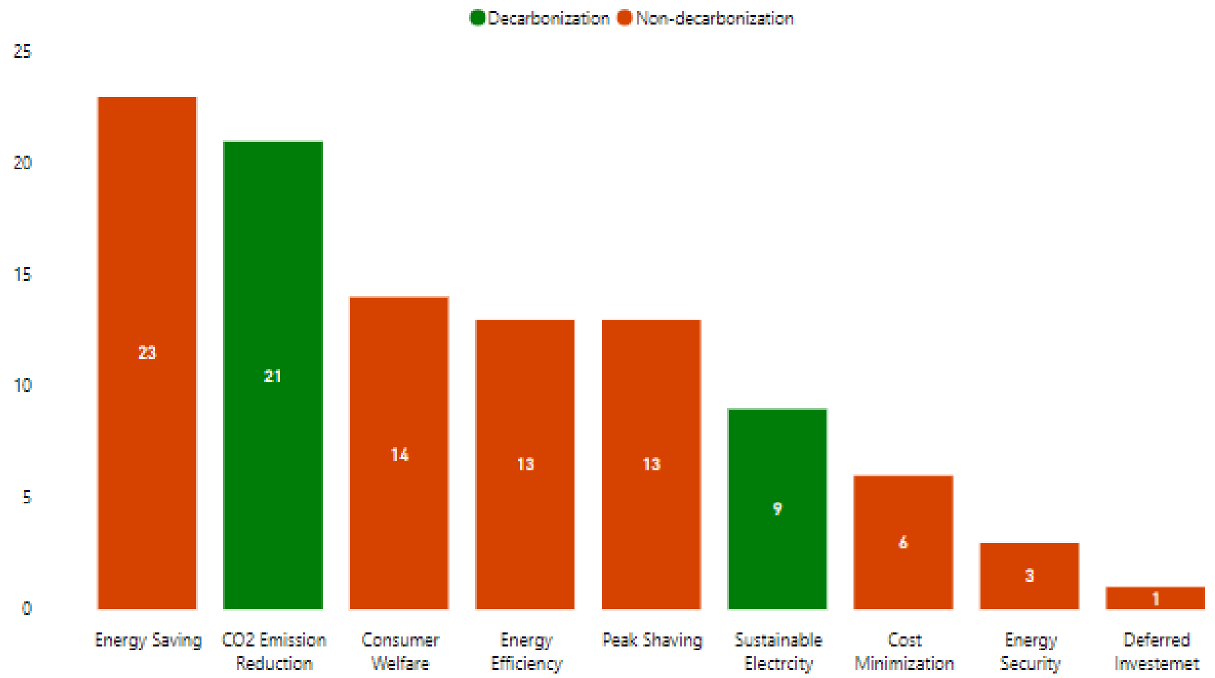

FIGURE 15. DSM research by themes
Source: (Figure is tabulated by authors)

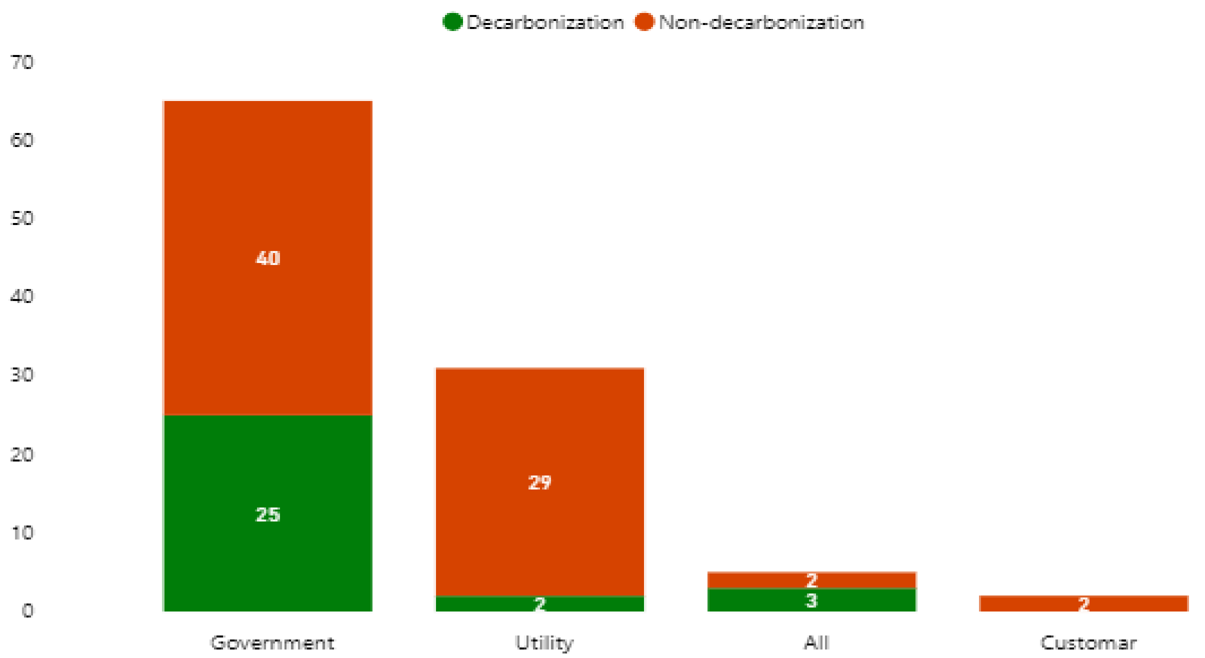

FIGURE 16. DSM articles by the implementer
Source: (Figure is tabulated by authors)

model increased from only one article between 2003-2010 to 19 (22%) between 2011-2018. However, the dominance of the simulation model has been worn away since the early 2000s. Its application fell significantly from about 67% between 1994-2002 to 39% between 2003-2010, and down to 26% between 2011-2018. Qualitative and experimental models did not see the light of the day until the works of Strengers (2010) and Bradley et al. (2016), respectively. Since then, scholars' attention has been drawn to the models with a share of 3.45% and 5.75% for qualitative and experimental, respectively (see Fig. 12).

DSM FOR ELECTRICITY DECARBONIZATION

The recent resurgence in DSM efforts has been triggered by growing concerns over shrinking utility reserve margins, fuel price volatility, and above all, climate change. As countries continue to pursue climate and energy policy measures, many pay more attention to the electricity decarbonization measures, of which demand-side angle is vital. Hence, there is a need for empirical studies on policy measures' effectiveness (Keay et al. 2012). DSM has evolved tremendously in recent times. First, policymakers and utility companies have come up with innovative policy instruments considered in this study. Second, DSM implementers now use the policy measures as a primary tool for achieving deep decarbonization (Neves et al. 2008) since the corresponding energy saving from policy implementation has been termed "low hanging fruits in the pursuit of climate mitigation" (Carley 2012).

DSM has been studied extensively in the scientific literature. However, policymakers' interests in designing measures with decarbonization as central policy trust are low compared to DSM's common goals. About 71% of published works centre on non-decarbonization themes and only 29% concentrate on CO_2 emissions reduction effectiveness of DSM policies. Different types of DSM policy instruments designed for addressing emissions from the electricity sector are shown in Fig. 13. The vast majority of these studies employed multiple instruments (43.3%), followed by energy efficiency standards (23.3%). The first and only researcher to examine DSM as a decarbonization tool was Intarapravich, where he considered demand-side as one of the greenhouse gas mitigation options for the Thai power sector in 1996. Between 2003-2010, the number of studies assessing the demand-side as a decarbonization tool has increased to 7 (54% of the articles within the period). Besides, 22 published articles between 2011-2018, although with a lower proportion of 25% compared to the previous period (Fig. 14).

Fig. 15 shows the distribution of the articles based on the core demand-side research themes. This study finds that saving/conserving energy remains the central policy focus of DSM with around 22% of papers, followed by CO_2 emissions reduction (20%), consumer welfare (13.5%), the efficiency of energy use (12.6%), peak saving by way of reducing peak demand (12.6%), electricity sustainability (8.7%), cost minimization of electricity production (5.8%), the security of power supply (2.9%), and only one paper consider deferment of plant investment as a theme.

DSM policies can be implemented directly by government agencies, utility companies or groups of electricity end-users. In this study, government agencies remain the largest DSM policymakers with a total of 65 papers, out of which 38.5% are centred on electricity decarbonization while the remaining 61.5% for other themes such as energy-saving, energy efficiency, consumer welfare, etc. Utility companies are

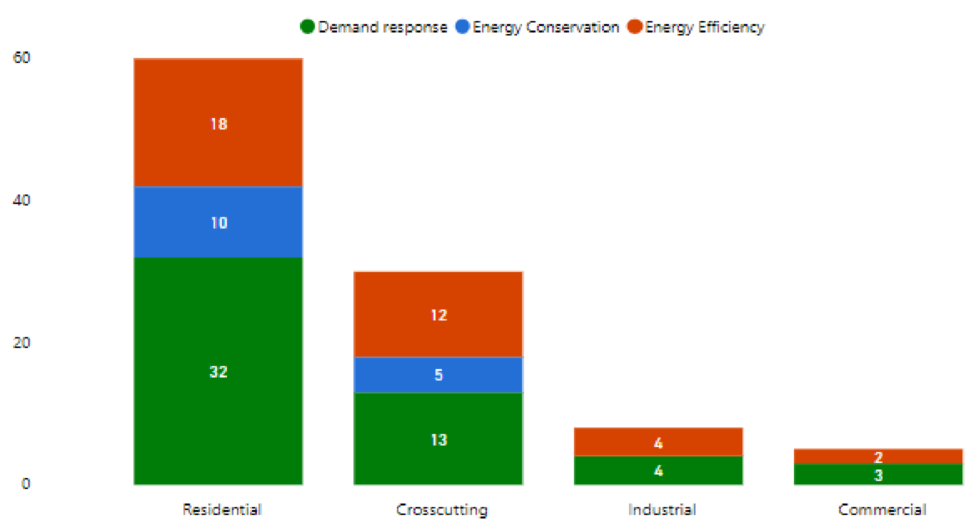

FIGURE 17. Reviewed studies by end-use sectors
Source: (Figure is tabulated by authors)

the next DSM policy initiators and implementers with a total of 31 (30%), out of which 94% of the policies are implemented for electricity peak saving, cost minimization, energy-saving, etc. In comparison, only 6% are channelled towards electricity decarbonization. Others are consumers, with 2% and 5% for policies implemented jointly (Fig. 16).

DSM IN END-USE SECTORS

As of 2016, the industrial sector remained the largest end-use of electricity in the Organisation for Economic Co-operation and Development (OECD) countries with a 31.9% share of electricity consumption which is slightly higher than that of the commercial (31.8%) and residential (31.1%). While in non-OECD economies, the industrial sector maintained a comfortable lead with 48.9%, followed by residential (24%) and the commercial sector (13.8%). However, as shown in Fig. 17, the residential sector attracts the most significant research interest with a share of 58%, out of which 32 (53%) papers are from DR literature, 18 (30%) from EE, and the remaining 10 (17%) from EC. Industrial and commercial sector shares are 8% and 5%, respectively, while the studies that cut across more than one sector are referred to as crosscutting (29%).

DISCUSSION AND CONCLUSION

Achieving the Paris Climate Ambitious target of limiting global warming is an enormous but surmountable challenge that spans well beyond supply-side solutions. According to Creutzig et al. (2018) and Mundaca et al. (Mundaca et al. 2018), a fundamental issue is the on-going evaluation and assessment of different portfolios of policy instruments. By influencing the periods, electricity end-users operate electric devices in such a way that the operations occur more with power generation with low CO_2 emission factors, could propel the direction and pace of decarbonization pathways and keep PA's 2°C goal within reach (S. J. G. Cooper et al. 2013). Some recent literatures have shown a mixed results on the determinants of carbon emissions, that are the financial development and trade openness (Rambeli et al. 2021) and elasticity of urbanisation (Yassin & Aralas 2020). To understand the recent state of the art of this field of research, we review one hundred and three empirical studies on policy instrument evaluations between 1994 and 2018. DSM policies are implemented across the world for different reasons, such as decarbonization (e.g. CO_2 emissions and sustainable electricity) and non-decarbonization (e.g. energy saving, efficiency, and security, peak saving, consumer welfare, investment deferment and of course, cost minimization). Our results reveal that these policies are always implemented for non-decarbonizing reasons. Energy-saving remains one of the main reasons countries apply DSM (Carroll et al. 2014; Sudarshan 2017). In terms of affordable electricity, consumer welfare is another important reason for initiating these policies (Y. Li et al. 2018; Ito & Ida 2018). In a considerably lesser time than other causes, researchers have cited carbon emissions reduction and sustainable electricity in the form of renewable energy as a policy objective of DSM (Khan 2018; Trancik et al. 2014). Currently, little attention has been paid to DSM policy measures, which are complementarily linked with supply-side solutions.

From a policy perspective, energy efficiency dominated the literature between 1994 – 2010, with energy conservation measures gaining momentum and demand response barely considered in the academic discourse during this period. EE has been a very successful DSM policy option when considering emissions reduction from the electricity sector (Haeri et al. 2018; Datta & Gulati 2014). Since 2011, demand response measures have overtaken EE policies as the main DSM policy tools. Its policy objectives are very diverse and pay more attention to the core DSM issues such as peak saving, energy saving, consumer welfare (Hayes et al. 2017; Yalcintas et al. 2015), so on. However, most DR policies do not always carve in emissions reduction as their primary policy objective. It has been described as the primary resource option for peak saving and balancing electricity demand and supply. But since carbon emissions mainly cause climate change, a comprehensive DR policy design is required to match electricity consumption and generation with low marginal emission factors (Stern et al. 2016).

Another important consideration is that DSM policies are implemented as policy tool kits rather than a single measure in reality. Despite the benefit of policy combinations, DSM scientific literature is still dominated by stand-alone policy evaluations, with 57% from developed countries while the remaining 43% are conducted in the developing world. This trend could be due to the administrative complexity and cost of implementing multiple DSM policies. The separation of different policy instrument impacts from the pool of measures amid a resurgence of climate change mitigation potential of DSM is another reason why there is single policy implementation than multiple by countries (Warren 2015). Within the field of DSM policy evaluation, much of the work has concentrated on policy impacts rather than policy mechanisms. The thesis contributes to filling this research gap by determining the key factors for success and failure for various DSM policies and countries (and sub-national states. The following are the countries where the policy package has been evaluated: USA (Khezeli & Bitar 2018), China (L. Li et al. 2018), Japan (Ito & Ida 2018), Finland (Olkkonen et al. 2017), UK (Granell et al. 2016), Iran (Derakhshan et al, 2016), and Ireland (Upton et al. 2015). It is, however, evidence from this analysis that more scientific research is needed in other countries concerning policy package assessment to identify potential policy conflict/Complementarity.

Many papers focus on end-use sectoral analyses such as industrial, commercial and residential sectors, with the primary aim of providing useful insights into the specific end-user DSM policy inputs. The industrial sector is unarguably responsible for the largest share of electricity demand, and scholars have empirically rolled out a roadmap to its sustainable pathways. However, research on industrial and commercial sectors has been undoubtedly under-represented, given their global electricity demand shares. Conversely, the residential sector receives an overwhelming research interest since 1994, making it the largest DSM research recipient. Meanwhile, one out of every three studies considers all end-use sectors in what is termed as crosscutting. More research is needed in this area, especially in both the industrial and commercial sectors, to offer purposeful inputs into the national energy policy implementation.

Overall, the top three modelling paradigms researchers used to assess DSM policies are; first, equilibrium models such as econometrics (Bye et al. 2018) discrete choice (Considine & Sapci 2016), and computable general equilibrium (Rodrigues & Linares 2015). Second, simulation models such as MAKMAL/TIMES (Blesl et al. 2007; Brinker et al. 2007), agent-based (Wang et al. 2018), scenario-based (Wakiyama & Kuramochi 2017). Lastly, optimization models using linear programming (Vu et al. 2018), mixed-integer linear/nonlinear programming (Lima et al. 2018; Bego et al. 2014), and dynamic programming (Chen et al. 2013). However, the popularity of econometric models is due to its ability not only to predict or measure how electricity consumption changes when the policy is introduced, but it also helps to understand and study the causal mechanisms that propel the policy effect. Furthermore, researchers may want to know if a rise in the price of electricity causes electricity demand to fall. It is easy to set up a regression to examine this relationship, but correlation/relationship does not necessarily imply causation. Therefore, the field of econometrics is fully equipped with capability intended to bring out causation from non-experimental and correlated data. However, since scholars do not content themselves with only optimal prediction makings, but also aim to understand causations, assumptions are required—most crucial of these are linearity and additivity. So, if these are not true, the model becomes invalid and descriptively misleading (Syll 2018). Therefore, more studies are needed in other modelling paradigms such as simulation model which can be used to understand in which circumstances a policy could succeed/fail, under what conditions and if indeed, the policy will have expected effect.

Many empirical studies on demand-side policy instruments are predominantly conducted in the United States, China, Japan, the United Kingdom, Australia, Germany, Sweden, and Switzerland. At the same time, DSM research in other countries has received little to no interest to date. It is, however, found that countries like India, France, South Korea, Brazil and Saudi Arabia are arguably under-represented. At the same time, nations like Russia and Canada are not represented despite their contribution to the growth of world electricity demand. For instance, only China and India were responsible for 70% of global electricity growth (3.1%) in 2017. Therefore, DSM policy evaluation is urgently needed to manage the future growth of electricity demand in these countries. The world reached a companion and unanimous decision to address the menace of climate change in 2015 during the conference of parties (COP 21) held in Paris. Few years after the agreement comes president Trump's withdrawal from PA, which many consider as an unfortunate and severe setback to implementing the INDCs. But contrary to what many expect, more researches have been conducted after Trump's withdrawal declaration, with most of them coming from the United States and emerging economies. Our findings dampen the fear of the bandwagon effect of the so-called withdrawal.

These research gaps could have serious implications for achieving ambitious climate targets. For residential end-users, DSM offers the possibility to manage their electricity bills through policy instruments. In commercial and industrial consumers, this would manifest in the form of the least cost of production and place them in more competitive ends from the global market. Apart from reducing the risk of a power outage, governments worldwide now use DSM to meet climate change mitigation targets.

ACKNOWLEDGEMENTS

The authors significantly acknowledged the financial support from Universiti Kebangsaan Malaysia (UKM) under the grant GUP-2018-015.

REFERENCES

Adika, C.O. & Wang, L. 2014. Demand-side bidding strategy for residential energy management in a Smart Grid Environment. *IEEE Transactions on Smart Grid* 5 (4): 1724–1733.

Adom, P.K. 2016. The long-run price sensitivity dynamics of industrial and residential electricity demand: the impact of deregulating electricity prices. *Energy Economics* 62: 43–60.

Al-Rubaye, S., Al-Dulaimi, A., Mumtaz, S. & Rodriguez, J. 2018. Dynamic pricing mechanism in Smart Grid communications is shaping up. *IEEE Communications Letters* 22 (7): 1350–1353.

Alasseri, R., Tripathi, A., Rao, T.J. & Sreekanth, K.J. 2017. A review on implementation strategies for Demand Side Management (DSM) in Kuwait through incentive-based demand response programs. *Renewable and Sustainable Energy Reviews* 77 (April): 617–635.

Ang, B.W.W. & Su, B. 2016. Carbon Emission intensity in electricity production: a global analysis. *Energy Policy* 94: 56–63.

Babatunde, K.A., Begum, R.A. & Fathin Faizah, S. 2017. Application of Computable General Equilibrium (CGE) to climate change mitigation policy: a systematic review. *Renewable and Sustainable Energy Reviews* 78(April): 61–71.

Babatunde, K.A., Fathin Faizah, S., Nor Ghani M.N., Rawshan A.B. & Mahmoud, M.A. 2021. Coherent or conflicting? assessing natural gas subsidy and energy efficiency policy interactions amid CO2 emissions reduction in Malaysia electricity sector. *Journal of Cleaner Production* 279: 123374.

Bager, S. & Mundaca, L. 2017. Making 'Smart Meters' smarter? insights from a behavioural economics pilot field experiment in Copenhagen, Denmark. *Energy Research and Social Science* 28 (April): 68–76.

Banerjee, S.G., Moreno, F.A., Sinton, J.E., Pirmiani, T. & Seong, J. 2016. *Regulatory Indicators for Sustainable Energy*. Washington, D.C. http://documents.worldbank.org/curated/en/538181487106403375/Regulatory-indicators-for-sustainable-energy-a-global-scorecard-for-policy-makers.

Bego, A., Li, L. & Sun, Z. 2014. Identification of reservation capacity in critical peak pricing electricity demand response program for sustainable manufacturing systems. *International Journal of Energy Research* 38: 728–736.

Bitar, E. & Xu, Y. 2017. Deadline differentiated pricing of deferrable electric loads. *IEEE Transactions on Smart Grid* 8(1): 13–25.

Blesl, M., Das, A., Fahl, U. & Remme, U. 2007. Role of energy efficiency standards in reducing CO2emissions in Germany: an assessment with TIMES. *Energy Policy* 35 (2): 772–785.

Boshell, F. & O.P. Veloza. 2008. Review of developed demand side management programs including different concepts and their results. *2008 IEEE/PES Transmission and Distribution Conference and Exposition: Latin America, T and D-LA*, 1–7.

Bradley, P., Coke, A. & Leach, M. 2016. Financial incentive approaches for reducing peak electricity demand, experience from pilot trials with a UK Energy Provider. *Energy Policy* 98: 108–120.

Briner, R.B. & Denyer. D. 2010. Systematic review and evidence synthesis as a practice and scholarship tool. In *The Oxford Handbook of Evidence-Based Management*, edited by Denise M. Rousseau, 112–129. Oxford: Oxford University Press.

Brinker, D.R., Birdwell, S.W. & Smeenk, D.A.. 2007. Sustainable development policies and measures: institutional issues and electrical efficiency in South Africa. *American Journal of Hospital Pharmacy* 7 (6): 212–229.

Bye, B., Fæhn, T. & Rosnes, O. 2018. Residential energy efficiency policies: costs, emissions and rebound effects. *Energy* 143: 191–201.

Carley, S. 2012. Energy demand – side management : New Perspectives for a new era. *Journal of Policy Analysis and Management* 31(1): 6–32.

Chen, W., Wang, X., Petersen, J., Tyagi, R. & Black, J. 2013. Optimal scheduling of demand response events for electric utilities. *IEEE Transactions on Smart Grid* 4(4): 2309–2319.

Cherp, A., Vinichenko, V., Jewell, J., Brutschin, E. & Sovacool, B. 2018. Integrating Techno-economic, socio-technical and political perspectives on national energy transitions: a meta-theoretical framework. *Energy Research and Social Science* 37: 175–190.

Considine, T.J. & Sapci, O. 2016. The effectiveness of home energy audits: a case study of Jackson, Wyoming. *Resource and Energy Economics* 44: 52–70.

Cooper, M. 2018. Governing the global climate commons: the political economy of state and local action, after the U.S. flip-flop on the Paris Agreement. *Energy Policy* 118: 440–454.

Cooper, S.J.G., Dowsett, J., Hammond, G.P., McManus, M.C. & Rogers, J.G. 2013. Potential of demand side management to reduce carbon dioxide emissions associated with the operation of heat pumps. *Journal of Sustainable Development of Energy, Water and Environment Systems* 1(2): 94–108.

Creti, A. & Nguyen, D.K. 2018. Energy and environment: transition models and new policy challenges in the post Paris Agreement. *Energy Policy* 122: 677–679.

Creutzig, F., Fernandez, B., Haberl, H., Khosla, R., Mulugetta, Y. & Seto, K.C. 2016. Beyond technology: demand-side solutions for climate change mitigation. *Annual Review of Environment and Resources* 41: 173-198.

Creutzig, F., Roy, J., Lamb, W.F., Azevedo, I.M.L, De Bruin, W.B., Dalkmann, H., Edelenbosch, O.Y. et al. 2018. Towards demand-side solutions for mitigating climate change. *Nature Climate Change* 8(4): 268–271.

Cui, W. & Li, L. 2018. A game-theoretic approach to optimize the time-of-use pricing considering customer behaviors. *International Journal of Production Economics* 201: 75–88.

Datta, S. & Gulati, S. 2014. Utility rebates for ENERGY STAR appliances: are they effective? *Journal of Environmental Economics and Management* 68(3): 480–506.

Derakhshan, G., Shayanfar, H.A. & Kazemi, A. 2016. The optimization of demand response programs in smart grids. *Energy Policy* 94: 295–306.

DOE. 2006. *Benefits of Demand R Esponse in Electricity Markets and Recommendations for Achieving Them*. Washington, D.C.

Dulleck, U. & Kaufmann, S. 2004. Do customer information programs reduce household electricity demand? - The Irish program. *Energy Policy* 32(8): 1025–1032.

ESMAP. 2018. *Regulatory Indicators for Sustainable Energy*. *ESMAP Report*. Washington, DC. https://jabar.bps.go.id/publication/download.html?nrbvfeve=OWE2M zQyMzgwZDEwNTgzOTdjMmRjNjhj&xzmn=aHR0cHM6Ly9qYW Jhci5icHMuZ28 uaWQvcHVibGljYXRpb24vMjAxNi8xMC8wMy85YTYzNDIzODBkMTA1ODM5N2 MyZGM2OGMvc HJvZHVrc2ktdGFuYW1hbi1wYWRpLWRhbi1wYWxhd2lqYS1qYXdhLWJhcmF0LT.

Eyre, N. 2013. Energy saving in energy market reform-the feed-in Tariffs Option. *Energy Policy* 52: 190–198.

Gary, S., Sharabaroff, A. & Semikolenova, Y. 2013. *Energy Efficiency: Lessons Learned from Success Stories*. Washington: World Bank Publications

Granell, Ramon, Colin J. Axon, David C.H. Wallom & Russell L. Layberry. 2016. Power-use profile analysis of non-domestic consumers for electricity tariff switching. *Energy Efficiency* 9 (3): 825–841.

Haeri, Hossein, Matei Perussi & James Stewart. 2018. Energy efficiency: The bird's-eye view. *Electricity Journal* 31 (4): 34–40.

Hayes, Barry, Igor Melatti, Toni Mancini, Milan Prodanovic & Enrico Tronci. 2017. Residential demand management using individualized demand aware price policies. *IEEE Transactions on Smart Grid* 8 (3). IEEE: 1284–1294.

Henriksson, Eva, Patrik Söderholm & Linda Wårell. 2012. Industrial electricity demand and energy efficiency policy: The role of price changes and private R&D in the Swedish pulp and paper industry. *Energy Policy* 47: 437–446.

Henriksson, Eva, Patrik Söderholm & Linda Wårell. 2014. Industrial electricity demand and energy efficiency policy: The case of the Swedish mining industry. *Energy Efficiency* 7 (3): 477–491.

Hinchliffe, S., R.V. Diemen, C. Heuberger & N. Macdowell. 2015. *A Study on Transitions in Electricity Systems Towards 2030 Examining: Australia, China, India, Malaysia, Singapore, South Africa and the United Kingdom*.

Honjo, Keita, Hiroto Shiraki & Shuichi Ashina. 2018. Dynamic linear modelling of monthly electricity demand in Japan: Time variation of electricity conservation effect. *PLoS ONE* 13 (4): 1–23.

IEA. 2015. *Capturing the Multiple Benefits of Energy Efficiency*. Paris.

IEA. 2018. *World Energy Outlook 2018*. Paris.

Intarapravich, D. 1996. Assessing greenhouse gas mitigation options for the Thai power sector. *Ambio* 25 (4): 233–239.

Ito, Koichiro & Takanori Ida. 2018. Moral suasion and economic incentives: Field experimental evidence from energy demand. *RIETI Discussion Paper Series* 10 (1): 240–267.

Kamal, Athar, Sami G. Al-Ghamdi & Muammer Koc. 2019. Revaluing the costs and benefits of energy efficiency: A systematic review. *Energy Research and Social Science* 54 (September 2018). Elsevier: 68–84.

Keay, Malcolm, John Rhys & David Robinson. 2012. *Decarbonization of the Electricity Sector - Is There Still a Place for Markets?*

Khan, Imran. 2018. Importance of GHG emissions assessment in the electricity grid expansion towards a low-carbon future: A time-varying carbon intensity approach. *Journal of Cleaner Production* 196. Elsevier B.V.: 1587–1599.

Khezeli, Kia & Eilyan Bitar. 2018. Risk-sensitive learning and pricing for demand response. *IEEE Transactions on Smart Grid* 9 (6): 6000–6007.

Kim, Min Jeong. 2016. Demand response of large-scale general and industrial customer using in-house pricing model. *Transactions of the Korean Institute of Electrical Engineers* 65 (7): 1128–1134.

Kim, Min Jeong. 2017. A field study using an adaptive in-house pricing model for commercial and industrial customers in Korea. *Energy Policy* 102 (December 2016). Elsevier: 189–198.

Kolokotsa, Dionysia. 2016. The role of smart grids in the building sector. *Energy and Buildings* 116. Elsevier B.V.: 703–708.

Kotchen, Matthew J. & Michael R. Moore. 2008. Conservation: from voluntary restraint to a voluntary price premium. *Environmental and Resource Economics* 40 (2): 195–215.

Li, Lanlan, Yue Yao, Ranran Yang & Kaile Zhou. 2018. Is it more effective to bring time-of-use pricing into increasing block tariffs? Evidence from evaluation of residential electricity price policy in Anhui province. *Journal of Cleaner Production* 181. Elsevier B.V.: 703–716.

Li, Yanxue, Weijun Gao, Yingjun Ruan & Yoshiaki Ushifusa. 2018. Demand response of customers in Kitakyushu smart community project to critical peak pricing of electricity. *Energy and Buildings* 168. Elsevier B.V.: 251–260.

Lima, Delberis A., Andrés Maurício Céspedes G., Érica Telles & Eidy Marianne Matias Bittencourt. 2018. Peak demand contract for big consumers computed based on the combination of a statistical model and a mixed integer linear programming stochastic optimization model. *Electric Power Systems Research* 154. Elsevier B.V.: 122–129.

Linares, Pedro & Xavier Labandeira. 2010. Energy efficiency: Economics and policy. *Journal of Economic Surveys* 24 (3): 573–592.

Liu, Yingqi. 2018. Role of a forward-capacity market to promote electricity use reduction in the residential sector—a case Study of the potential of social housing participation in the electricity demand reduction Pilot in the UK. *Energy Efficiency* 11 (4). Energy Efficiency: 799–822.

Loi, Tian Sheng Allan & Soh Leng Loo. 2016. The impact of Singapore's residential electricity conservation efforts and the way forward. Insights from the bounds testing approach. *Energy Policy* 98. Elsevier: 735–743.

Martín-Martín, Alberto, Enrique Orduna-Malea, Mike Thelwall & Emilio Delgado López-Cózar. 2018. Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. *Journal of Informetrics* 12 (4): 1160–1177.

Meyabadi, A. Fattahi & M.H. Deihimi. 2017. A review of demand-side management: reconsidering theoretical Framework. *Renewable and Sustainable Energy Reviews* 80 (January 2016). Elsevier Ltd: 367–379.

Morris, Peter, Laurie Buys & Desley Vine. 2014. Moving from outsider to insider: Peer status and partnerships between electricity utilities and residential consumers. *PLoS ONE* 9 (6).

Mundaca, L., Ürge-Vorsatz, D. & Wilson, C. 2018. Demand-side approaches for limiting global warming to 1.5 °C. *Energy Efficiency*.

Neves, Luís Pires, António Gomes Martins, Carlos Henggeler Antunes & Luís Cândido Dias. 2008. A multi-criteria decision approach to sorting actions for promoting energy efficiency. *Energy Policy* 36 (7): 2351–2363.

Nong, Duy & Mahinda Siriwardana. 2018. Effects on the U.S. economy of its proposed withdrawal from the Paris agreement: a quantitative assessment. *Energy* 159: 621–629.

OECD/IPEEC. 2016. G7 Hamburg initiative for Sustainable energy security. Analytical report on instruments for energy efficiency.

Olkkonen, Ville, Samuli Rinne, Aira Hast & Sanna Syri. 2017. Benefits of DSM measures in the future finnish energy system. *Energy* 137. Elsevier Ltd: 729–738.

Ouedraogo, Nadia S. 2017. Africa energy future: Alternative scenarios and their implications for Sustainable Development Strategies. *Energy Policy* 106 (April). Elsevier Ltd: 457–471.

Oyeniran, Wasiu Ishola & Kazeem Alasinrin Babatunde. 2015. Growth thresholds and environmental degradation in Sub-Saharan African Countries : An Exploration of Kuznets Hypothesis. *International Journal of Management, Accounting and Economics* 2 (8): 858–871.

Rambeli, N., Awang Marikan, D.A., Hashim, E., Mohd. Ariffin S.Z., Hashim, A., Podivinsky, J.M., 2021. The determinants of carbon dioxide emissions in Malaysia and Singapore. *Jurnal Ekonomi Malaysia,* 55(2): 107 - 119

Rhodes, Christopher J. 2017. US Withdrawal from the COP21 Paris Climate Change Agreement, and its possible implications. *Science Progress* 100 (4): 411–419.

Rodrigues, Renato & Pedro Linares. 2015. Electricity load level detail in computational general equilibrium– Part II – Welfare impacts of a demand response program. *Energy Economics* 47. Elsevier B.V.: 52–67.

Rogelj, Joeri, Gunnar Luderer, Robert C. Pietzcker, Elmar Kriegler, Michiel Schaeffer, Volker Krey & Keywan Riahi. 2015. Energy system transformations for limiting end-of-century warming to below 1.5 °C. *Nature Climate Change* 5 (6). Nature Publishing Group: 519–527.

Rousseau, Denise M, Joshua Manning & David Denyer. 2008. Evidence in management and organizational science: Assembling the field's full weight of scientific knowledge through syntheses. *The Academy of Management Annals* 2 (August): 475–515. http://ssrn.com/abstract=1309606.

Schaeffer, Roberto, Claude Cohen, Anna Cecília J. de Aguiar & Glaucio V.R. Faria. 2009. The potential for electricity conservation and carbon dioxide emission reductions in the household sector of Brazil. *Energy Efficiency* 2 (2): 165–178.

Schanes, Karin, Karin Dobernig & Burcu Gözet. 2018. Food Waste Matters - A systematic review of household food waste practices and their policy implications. *Journal of Cleaner Production* 182. Elsevier Ltd: 978–991.

Silva, Carlos & Shahriyar Nasirov. 2017. Chile: paving the way for sustainable energy planning. *Energy Sources, Part B: Economics, Planning and Policy* 12 (1). Taylor & Francis: 56–62.

Sousa, José L. & António G. Martins. 2018. Portuguese plan for promoting efficiency of electricity end-use: Policy, Methodology and Consumer Participation. *Energies* 11 (5).

Stern, Frank, Maggie Shober, Matt Tanner & Dan Violette. 2016. Greenhouse gas reductions from demand response: Impacts in three U.S. markets. In *International Energy Policies & Programmes Evaluation Conference*.

Strengers, Yolande. 2010. Air-Conditioning Australian Households: The impact of dynamic peak pricing. *Energy Policy* 38 (11). Elsevier: 7312–7322.

Swisher, Joel, Lena Christiansson & Claes Hedenström. 1994. Dynamics of energy efficient lighting. *Energy Policy* 22 (7): 581–594.

Syll, Lars. 2018. The main reason why almost all econometric models are wrong. *WEA Commentaries*, June. https://www.worldeconomicsassociation.org/newsletterarticles/econometric-models-wrong/.

Trancik, Jessika E, Michael T Chang, Christina Karapataki & Leah C Stokes. 2014. Effectiveness of a segmental approach to Climate Change Policy. *Environ. Sci. Technol* 48: 27–35.

Tronchin, Lamberto, Massimiliano Manfren & Benedetto Nastasi. 2018. Energy efficiency, demand Side management and energy storage technologies – A critical analysis of possible paths of integration in the built environment. *Renewable and Sustainable Energy Reviews* 95 (April). Elsevier Ltd: 341–353.

UNIDO. 2009. Demand-Side management. In *Sustainable Energy Regulation and Policymaking for Africa: Training Manual*. Vienna: United Nations on Industrial Development Organization.

Upton, J., M. Murphy, L. Shalloo, P. W.G. Groot Koerkamp & I. J.M. De Boer. 2015. Assessing the impact of changes in the electricity price structure on dairy farm energy costs. *Applied Energy* 137. Elsevier Ltd: 1–8.

Ürge-Vorsatz, Diana, Agnes Kelemen, Sergio Tirado-Herrero, Stefan Thomas, Johannes Thema, Nora Mzavanadze, Dorothea Hauptstock, et al. 2016. Measuring multiple impacts ofl low-carbon energy options in a Green Economy Context. *Applied Energy* 179: 1409–1426.

von Stechow, C., Minx, J.C., Riahi, K. , Jewell, J. , McCollum, D., Callaghan, M.W., Bertram, C., Luderer, G., & Giovanni, B. 2016. 2°C and SDGs: United they stand, divided they fall? Environmental Research Letters 11(3): 34022.

Vu, Dao H., Kashem M. Muttaqi, Ashish P. Agalgaonkar & Abdesselam Bouzerdoum. 2018. Customer reward-based demand response program to improve demand elasticity and minimise financial risk during price spikes. *IET Generation, Transmission & Distribution* 12 (15): 3764–3771.

Waide, Paul, Benoît Lebot & Mark Hinnells. 1997. Appliance energy standards in Europe. *Energy and Buildings* 26 (1): 45–67.

Wakiyama, Takako & Takeshi Kuramochi. 2017. Scenario analysis of energy saving and CO2 emissions reduction potentials to ratchet up Japanese mitigation target in 2030 in the residential sector. *Energy Policy* 103 (December 2016). Elsevier: 1–15.

Wang, Yu, Haiyang Lin, Yiling Liu, Qie Sun & Ronald Wennersten. 2018. Management of household electricity consumption under price-based demand response scheme. *Journal of Cleaner Production* 204. Elsevier B.V.: 926–938.

Warren, Peter. 2014. A Review of demand-side management policy in the UK. *Renewable and Sustainable Energy Reviews* 29. Elsevier: 941–951.

Warren, Peter. 2015. Demand-Side Management Policy: Mechanisms for success and failure. University College London.

Warren, Peter. 2018. Demand-Side Policy: Global evidence base and implementation patterns. *Energy and Environment* 29 (5): 706–731.

Wilson, Charlie, Arnulf Grubler, Kelly S. Gallagher & Gregory F. Nemet. 2012. Marginalization of end-use technologies in energy innovation for climate protection. *Nature Climate Change* 2 (11). Nature Publishing Group: 780–788.

Yalcintas, Melek, William T. Hagen & Abidin Kaya. 2015. An analysis of load reduction and load shifting techniques in commercial and industrial buildings under dynamic electricity pricing schedules. *Energy and Buildings* 88. Elsevier B.V.: 15–24.

Yao, Leehter, Wei Hong Lim & Teng Shih Tsai. 2017. A real-time charging scheme for demand response in electric vehicle parking station. *IEEE Transactions on Smart Grid* 8 (1): 52–62.

Yassin, J., Aralas S. 2020. The service sector and carbon emission nexus: revisiting environmental Kuznets curve. *Jurnal Ekonomi Malaysia*. 54(2): 113 - 124

Zhang, F. 2015. Energy price reform and household welfare: The case of Turkey. *Energy Journal* 36 (2): 71–95.

Zhang, Z., Cai, W. & Feng, X. 2017. How do urban households in China respond to increasing block pricing in electricity? Evidence from a Fuzzy Regression Discontinuity Approach *Energy Policy* 105 (May 2016). Elsevier: 161–172.

Zivin, Joshua Graff & Kevin Novan. 2016. Upgrading efficiency and behavior: Electricity savings from Residential Weatherization Programs. *Energy Journal* 37 (4): 1–23.

Fathin Faizah Said
Faculty of Economics and Management
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor
MALAYSIA.
E-mail: fatin@ukm.edu.my

Kazeem Alasinrin Babatunde
Faculty of Management Sciences
Alhikmah University
Adewole Estate, PMB 1601 Ilorin
NIGERIA.
E-mail: qozeemalasinrin@yahoo.com

Nor Ghani Md Nor
Faculty of Economics and Management
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor
MALAYSIA.
E-mail: norghani@ukm.edu.my

Moamin A. Mahmoud
College of Computing & Informatics (CCI)
Universiti Tenaga Nasional (UNITEN)
Putrajaya Campus, Jalan IKRAM-UNITEN
43000 Kajang, Selangor
MALAYSIA.
E-mail: moamin@uniten.edu.my

Rawshan Ara Begum
Institute of Climate Change
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor
MALAYSIA.
E-mail: rawshan@ukm.edu.my

* Corresponding author