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Data Collection Surveys on the Cornerstones of the Water-Energy Nexus: A Systematic Overview

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ABSTRACT There is no doubt that energy and water are cornerstones of life and that they are closely related to one another. Climate change, population growth, and urbanization rates are dramatically driving demand for both energy and water. To understand the inextricability between these two basic necessities of life, a nexus approach has proven useful. This paper provides an overview of recent studies to understand energy and water use data collected from surveys of urban and rural communities. The paper reviews worldwide case studies of water and energy demand, and factors influencing consumption, including household characteristics, consumer behavior, and the relationship between technology and demand. The paper also looks into coupled water-energy conservation studies. This review finds that most research still treats water and energy separately rather than jointly in a nexus approach, due in part to sectoral fragmentation, but also to important differences in data structure, time scales, and applications. Data collection methodologies and data analysis techniques used in case studies are also summarized. They indicate that nexus methodologies are mainly applied to the supply side of the water-energy nexus, but not to the demand side. By coupling water and energy data collection and analysis, this paper provides insights for conserving water and energy, especially on the demand side. This paper thus serves as a systematic overview for future water-energy nexus data collection surveys and analyses.

INDEX TERMS Data analysis, energy consumption, literature review, survey research, water-energy nexus, water consumption.

I. INTRODUCTION

Research on the water-energy nexus reflects the inseparable links between water and energy, which are cornerstones of smart community infrastructure [1]. The interaction between water and energy networks is driven in part by consumers demand [2]. According to the ‘‘Global Energy Statistical Yearbook’’ [3], there was an increase in both global energy and electricity consumption (e.g., in 2018 by 2.3% and 3.5%, respectively). The yearbook identified China and US as countries consuming the most energy and electricity compared to other countries in the world [3]. Residential and commercial buildings contribute highly to total energy demand. For the US, buildings and households accounted for 40% of the overall USA energy consumption [4], while in China, building energy demand reached 20% of total energy consumption [5]. The portion of residential energy demand in rural households in other zones of the world is also high. For instance, rural household energy consumption in Myanmar, Bangladesh, Nepal, and the majority of India's regions was over 70% of total rural energy use [6].

Water demand has become increasingly important in the last decade due to both population and economic growth. As of 2019, the world population was reported to be around 7.75 billion. Population growth is forecasted to increase to 9.7 billion by 2050, according to the ‘‘United Nation (UN) Prospects’’ [7]. Population growth reduces the gross per capita renewable water supply, while economic growth can accelerate consumption of those supplies and deplete non-renewable groundwater. According to the UN estimates, 30%

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of the world's population may experience a water shortage by 2025 [7].

In 2018 an estimated 44% of the withdrawn fresh water around the world was consumed, while the rest was discharged as wastewater [8]. Water management research deals with these issues. As shown in [9], for example, residential water management is increasingly assessed from a political standpoint that includes and extends beyond traditional economic and technical aspects.

Recently, a number of review studies of the water-energy nexus [10]–[17] adopt a range of different approaches that include: integrated nexus frameworks [10], [11]; nexus applications in specific locations [12]; practical nexus tools for macro-assessments [13]; urban water-energy management subject to environment risks [14]; management and policy tools for water-energy-food systems [15], [16]; and sensor technologies for the water-energy nexus [17]. Hamiche *et al.* in [10] conducted a review of water-energy nexus research that considered its evolution and progress regarding information, methodologies, and knowledge over the past 40 years up to 2016. The review pointed out knowledge gaps and challenges that require a broader view, complex models, comprehensive management frameworks, and multi-dimensional analysis. Meanwhile, another review classified different nexus types (i.e., water-energy, water-food, water-energy-food, and climate related nexus); major nexus regions (i.e., Asia, EU, Oceania, North America, South America, Middle East and Africa); and nexus keywords [11]. Within the scope of Abu Dhabi, authors in [12] reviewed the water-energy nexus approach for designing, operating, and policy-making to harmonize the water and energy sectors. A survey of recent scientific literature on the water-energy nexus was conducted in [13] to point out the necessity of ''governing'' and ''implementing'' the nexus approach. A survey was conducted in [14] over 20 regions and 4 countries considered the influence of water risks on energy intensities. In [15], [16], a review of decision-making tools to ensure robust governance of energy-water-food nexus was introduced. The review study in [15] focused on technical approaches such as mathematical optimization, agent-based modelling, and game theory while [16] introduced the most common modeling tools available in practice. A review of sensor technologies for water-energy nexus was presented in [17] that included bio-technology, nano-technology and wireless networks to measure the efficiency of inter-related processes in the water-energy sectors.

As previously mentioned, many of the linkages in water-energy nexus research address the supply side from an engineering perspective, where the production of water and energy are means of supplying these resources. These approaches are often called ''water for energy'' and ''energy for water,'' as mentioned in [18]. Another important aspect of water-energy linkages is on the demand side where these two resources are essential cornerstones of human existence. Many recent studies focus separately on energy and water consumption patterns in various areas (e.g., urban and rural communities), types of buildings, and sectors to determine important factors affecting energy and water consumption [19]. Unfortunately, research studies on the nexus with respect to the demand side are relatively few in number. One recent study showed that when the ISO 50001 Energy Management System is applied to water, positive results on the demand side of water were achieved as well as for energy use [20]. Hence, it is necessary to identify studies focusing on water-energy demand, due in part to the strong correlation between water and energy consumption, and also to the need to broaden the approach from the technical and engineering arena to socio-psychological considerations [18].

Toward this end, this paper presents an overview of the most recent water-energy case studies, focusing on water-energy consumption and demand. Specifically, the study focuses on data-collection surveys since behavioral and data science are fast emerging topics in both research and industry communities. The paper reviews practical case studies of water-energy consumption patterns and examines factors affecting water-energy consumption as well as coupled water-energy conservation studies. The review observes that most research still treats water and energy separately, rather than jointly studying these resources in a nexus approach. The barriers to integration include not only sectoral fragmentation, but also the differences in data structure, time scales, and applications on a global scale. The case studies are classified according to data collection methodologies and data analysis techniques. As anticipated above, nexus research methodologies are mainly applied to the supply side of water and energy sectors with few linkages on the demand side beyond the technical ones. This overview of water-energy nexus studies, provides insights and recommends remedies for conserving water and energy that focus on the demand side. The paper also serves as a foundation for future water-energy nexus data-collection surveys, given the growing interest in behavioral and data science from industries.

The paper is organized as follows: Section II presents the conceptual framework and bibliographic search methods. Section III provides an overview of results on water-energy global consumption. Section IV reviews research on energy consumption data collection, while Section V considers water use data collection research. Section VI looks at the coupling of water-energy resources defined as the water-energy nexus. In Section VII, insights and remedies for water-energy conservation are presented, and a conclusion is provided in Section VIII.

II. CONCEPTUAL FRAMEWORK AND BIBLIOGRAPHIC SEARCH METHODS

This review of water-energy data research employed rigorous bibliographic search and screening methods which searched databases including Compendex, Google Scholar, and Web of Knowledge. Keywords were used in advanced searches for ''urban'' OR ''rural'' AND ''water'' AND/OR ''energy'' AND ''demand'' OR ''use''. The search years were limited to a range from 2002 up to 2020 to review the most recent

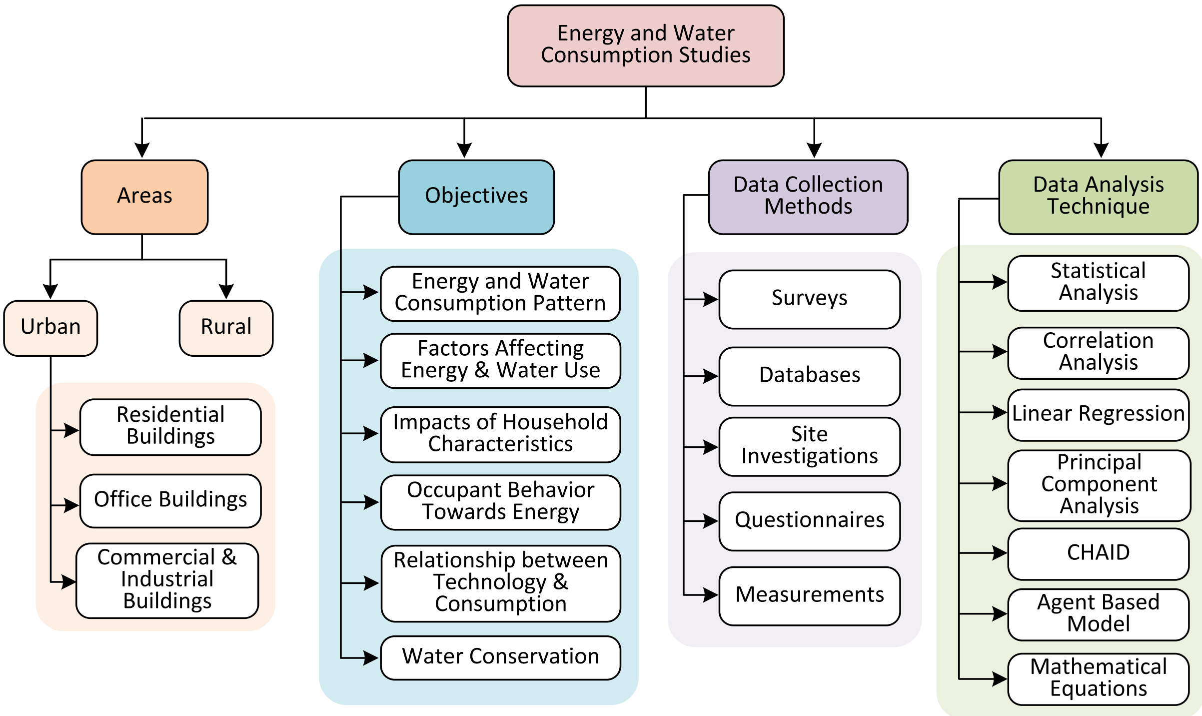

FIGURE 1. **Classification of studies on water-energy consumption based on different criteria including studied areas, objectives, data collection and analysis methodologies.**

research available in these rapidly growing subfields. The choice of search years was premised on the increased concern for water-energy issues driven by the Millennium Development Goals (MDGs). The results of this search helped shape a conceptual framework for reviewing the current literature on energy and water use. As shown in Fig. 1, the overall classification of studies is based on the four major categories of regions, objectives, data collection procedures, and data analysis techniques.

The classification by regions includes two subcategories: urban and rural. This classification method was used to address the distinct consumption patterns and factors influencing demand in these regions. The urban category includes residential, office, commercial, and industrial buildings. While rural regions utilize diversified sources of energy (i.e., coal, biogas, LPG, crop residuals, firewood, etc.) in addition to electricity for farm operations, the dominant type of water and energy consumption reviewed in this study involved household uses.

In the second classification, studies are grouped by the six main research objectives shown in Fig. 1, e.g., identifying consumption patterns, factors affecting water-energy use, relationships between technology and consumption, etc. We observed five data collection methods used in the reviewed studies. Last, the data are processed by techniques that are classified into seven types shown in Fig. 1.

III. GLOBAL WATER-ENERGY CONSUMPTION

An important cornerstone of social and economic development is electricity [21]. By looking at electricity consumption patterns in various continents in Fig. 2 [22], it can be noticed that electricity consumption has an increasing pattern globally. World electricity consumption increases at a faster rate than the rates of other forms of energy not only due to the development witnessed by countries, but also as a result of the growing global population. For instance, Asia has the highest share of the increase in global electricity consumption in 2018 as shown in Fig. 2. While China consumed more than half of the electricity of the whole Asia as shown in Fig.3 [23], power consumption also increased in Japan, India, Indonesia, and South Korea over the years. Note that the "Whole Asia" bar in Fig. 3 includes all Asian countries such as Japan, Indonesia, India, China, etc., which is compared to individual countries of Asia. For other countries, e.g., the US, electricity consumption has stayed stable since 2014 (3895TWh) until 2017 when it decreased(3884TWh) [22]. A stable electricity consumption pattern is also observed in Europe over recent years. This trend in the US and EU electricity consumption can be ascribed to the improvement in energy efficiency techniques. In comparison, electricity consumption has a highly increasing pattern in Egypt with 4.6% growth rate per year on average from 2014 to 2018 [22]. One possible reason for this increase is the rise in GDP in Egypt with a GDP growth rate of 5.6% in 2017 [24].

Similarly, global water consumption around the world showed an increasing pattern in years. Fig.4 presents global water consumption from the year 1990 to 2014 [25]. Due in large measure to the growing global population and economy, communities have moved towards more consumption on water. This consumption comes from freshwater

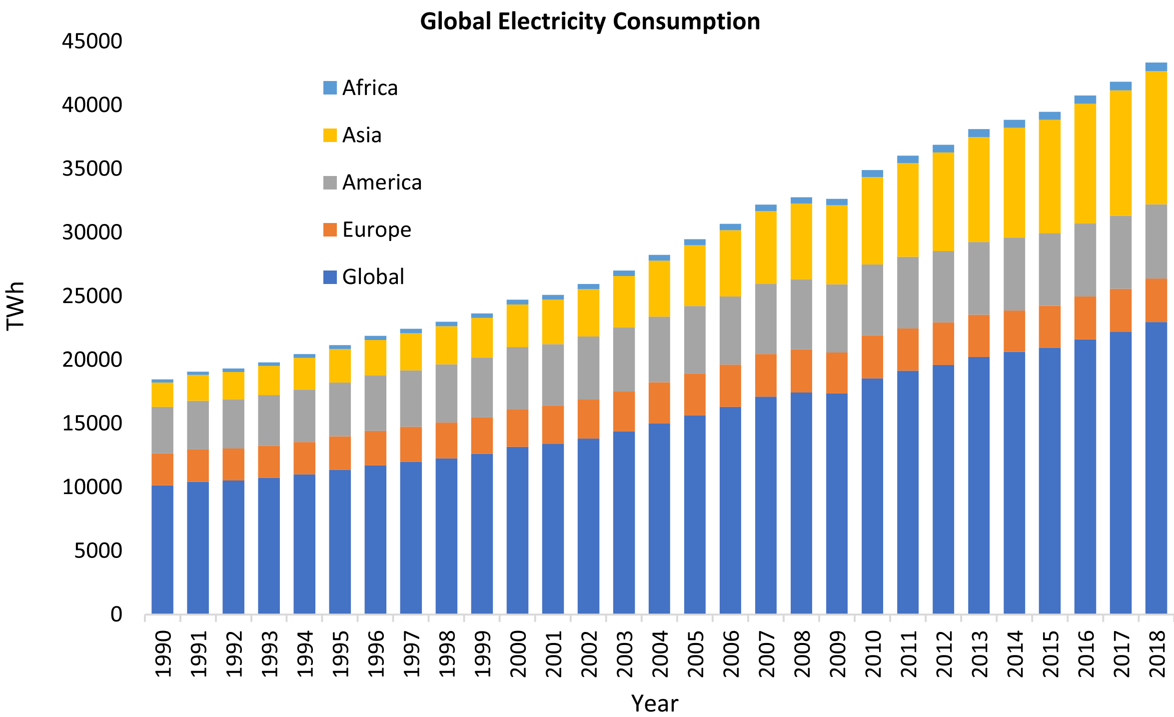

FIGURE 2. Global electricity consumption from 1990 to 2018 (as per the data in [22]).

withdrawals for agriculture, industry, and municipal use. Rates of global water utilization has increased sharply from the 1950s; however, the rate of increase is slowing down, starting from 2000s and declined in some countries, such as the U.S. [25].

Given the increase in both electricity and water consumption, the need for studies in these fields comes into the picture. Therefore, the next two sections will elaborate on the energy and water consumption data collection and analysis studies separately and then jointly.

IV. ENERGY CONSUMPTION

Settlements are classified into urban and rural regions based on settlement size, density, and activities [26], [27]. Energy consumption varies from one region to another as it is driven by appliance ownership, income, electrification, etc., which are sometimes associated with their urban or rural characteristics [28]–[31]. Differences in regions are expected to result in different factors affecting water-energy use. However, rural settlements in many regions are increasingly acquiring urban amenities in ways that make them "rurban" "peri-urban" or "exurban" [32]. Many practical analyses of energy consumption and consumer action in different types of settlements are summarized in Table 1 and discussed in this section.

Regarding energy consumption, the most popular form of energy is electricity where domestic electricity consumption plays an important role in satisfying energy demand. One review paper [19] conducted an investigation that identified more than 62 factors affecting the domestic electricity consumption (i.e., 13 socio-economic factors, 12 dwelling factors, and 37 appliance factors). However, that review [19] included factors at the household level only. The large number of factors found in [19] raises a concern about the possible high correlation among these factors. Other papers in the literature conducted data-based studies of urban residential consumption [33]–[38], urban commercial, industrial and office building consumption [39]–[47], and rural energy consumption [6], [48]–[53] as shown in Table 1. Unlike energy consumption in urban areas, rural areas use more diversified types of energy, and the dominant demand comes from households.

A. THE URBAN SECTOR

Energy consumption plays a vital role in ecological urban planning and valuation [54], [55]. The urban sector includes several important zones: residential, industrial and commercial [56], [57]. This section provides an overview of energy consumption surveys conducted in these zones, aimed at studying demand patterns and factors influencing those patterns.

1) RESIDENTIAL BUILDINGS

Residential building surveys target the relationship among different factors governing household energy consumption. These surveys have included different regions of the world such as China [33], USA [34], [35], United Arab Emirates [36], and France [37], [38]. They either focused on understanding the link between residential behavior and energy consumption [33]–[35], [56], [57]; energy

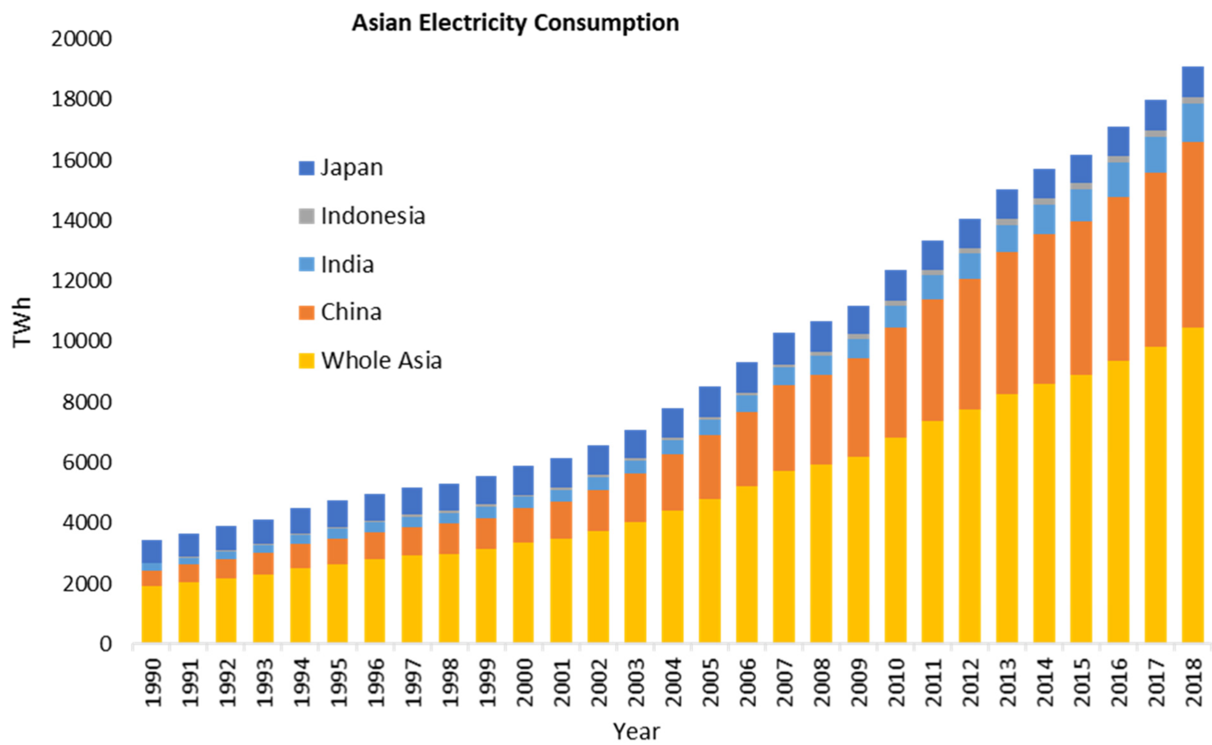

FIGURE 3. Asia electricity consumption from 1990 to 2018 (as per the data in [23]).

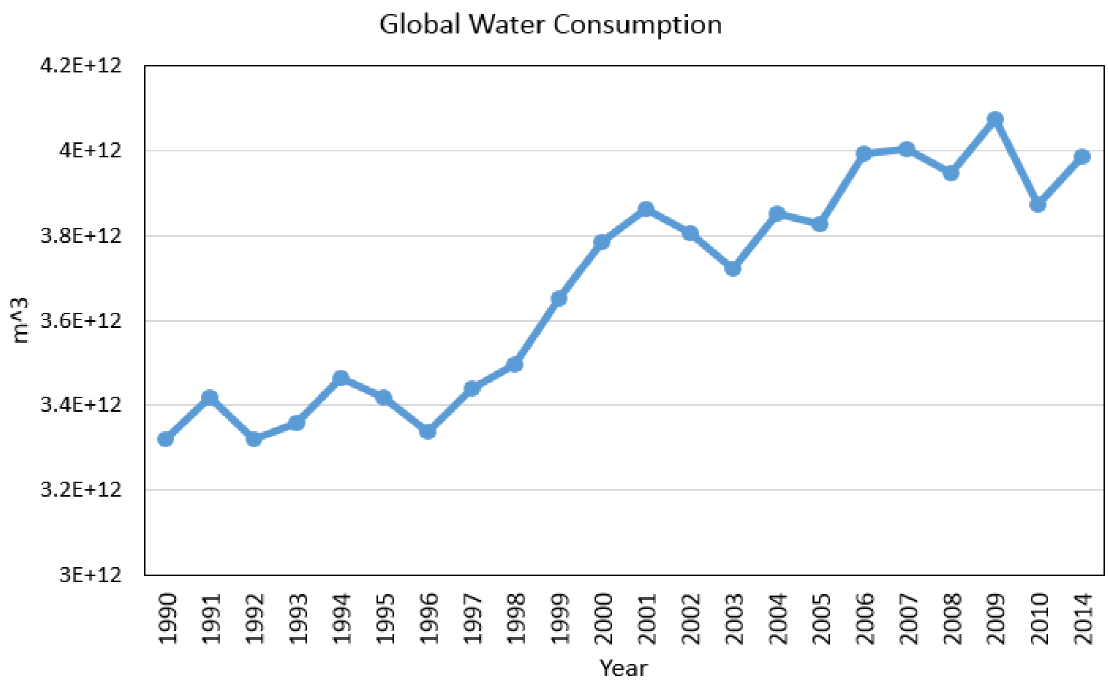

FIGURE 4. Global water consumption from 1990 to 2014 (as per the data in [25]).

savings [37], [38]; or socio-economic, dwelling, and regional characteristics that affect energy consumption [38]. Chen *et al.* [33] studied the influence of household features and occupants attitudes toward home energy consumption. For this purpose, two seasonal surveys (winter and summer) were distributed in Hangzhou, China. Data collection was

TABLE 1. Summary of reviewed works on energy consumption.

Objective of the Study	Country	Year Published	Reference
Urban residential data			
Household characteristics and occupant behavior	China	2013	[33]
Behavioral, physical and socio-economic parameters	USA	2011	[34]
Connection between building technology and residential behavior.	USA	2017	[35]
Activities and motivations of dwellers towards saving energy	UAE	2017	[36]
Energy saving actions	France	2016	[37]
Dwelling type size, heterogeneity in French household energy consumption	France	2017	[38]
Urban commercial, industrial and office building data			
Factors hindering the use of energy efficiency technologies in both the industrial and commercial sectors	Ukraine	2017	[39]
Identifying energy consumption and usage behavior, and types of energy supply and equipment	Bangladesh	2016	[40]
Assessing the effect of extreme energy consumers on energy conservation	USA	2015	[41]
Investigating the occupant's impact on energy consumption	USA	2017	[42]
Determining the motivating factors for energy use in office buildings	Norway	2012	[43]
Analyzing the energy consumed in office buildings	Inner Mongolia	2016	[44]
Defining the elements influencing energy demand in office buildings	China	2016	[45]
Investigating the energy usage of lights in large office buildings	China /Hong Kong	2015	[46]
Inspecting energy consumption in office and hospitals	Northern China	2017	[47]
Rural areas data			
Studying energy sources and energy consumption of households	China	2015	[48]
Studying the energy consumption pattern and what factors influence it	Bangladesh	2010	[6]
Finding factors that can change Chinese energy consumption	China	2013	[49]
Simplifying energy consumption and air pollutants in a region	China	2006	[50]
Studying household energy consumption: technical and economic issues	China	2014	[51]
Investigating energy consumption behavior	China	2002	[52]
Determining household energy consumption pattern and factors affecting the choice of energy	India	2009	[53]

from 642 individuals in the winter season and 838 in the summer season. To analyze the collected data, the ''Statistical Package for the Social Sciences'' (SPSS) was used for the statistical analyses. Such analyses included bivariate correlation analysis, path analysis, and multiple linear regression. For example, results showed that a resident's age has more impact than income on energy consumption. This result may reflect the fact that as the age of household members increases, the so does the size of the household population. Elderly persons have weaker thermoregulation, which can lead to higher heating and cooling preferences. A larger and older household will therefore consume more energy to meet its hot water, heating, cooking and other energy-related needs.

To examine the effects of behavior, physical elements, and social-economic variables on energy used for cooling residential buildings, the authors of [34] used the USA ''Residential Energy Consumption Survey'' (collected data from 2,718 units). A general linear model and a path analysis were performed to analyze the survey data. Results indicated that climate significantly affects energy demand in comparison with household income. Parameters such as occupant behavior, air conditioning and house types (physical), and income and household size (socioeconomic) were found to be important factors affecting energy use.

In [35], Zhao *et al.* collected data from more than 300 residential units in the USA to find the connection between building technology and residential behavior. Survey research data were analyzed using multivariate regression techniques. Results indicated behaviors with a direct correlation to energy consumption. These behaviors were winter and summer temperatures, washing and drying machine utilization, and awareness of building energy systems. Among these factors, two behaviors were noticed to be indirectly correlated to energy consumption (temperature setting in winter, and knowledge about building systems).

Moving to the Middle East, energy saving in campus buildings was an important topic of research. Azar and Al Ansari [36] surveyed residents of a green university campus in the city of Abu Dhabi, United Arab Emirates to study relationships between the activities and motivations of dwellers towards saving energy. Survey research data were gathered from 227 occupants of the university grounds, and were analyzed through both principal component analysis and multilinear regression. Findings indicated that a stated motivation toward energy saving may not result in actions to actually limit energy use.

2) INDUSTRIAL, COMMERCIAL, AND OFFICE BUILDINGS

Non-residential energy use is large and growing in urban regions. Hochman and Timilsina [39] surveyed 509 companies to discover what can hinder the use of energy efficiency technologies in both the industrial and commercial sectors in Ukraine. The research data collected from surveys were used in empirical models. They quantified how the lack of knowledge and awareness constrains the utilization of energy efficiency technologies. In addition, financial costs can restrict it especially for small companies. In [40], Habib *et al.* conducted a survey of Kojima Lyric Garments (an industrial company) in Bangladesh for the purpose of collecting data on energy consumption, usage behavior, types of energy supply, and equipment. Through mathematical modeling, the authors discovered that electric motors were responsible for 70% of the energy consumption. Also, it was found that savings in energy and thus billings per year could be improved by using variable speed drives. Azar and Menassa [41] piloted a study focusing on commercial buildings in the United States to assess the effect of extreme energy consumers on adoption of energy conservation practices. Research data were acquired from the ''Commercial Building Energy Consumption Survey'' that targeted 395 buildings in the United States. An agent-based model was used to investigate the influence of extreme use on the energy performance of the studied buildings. The results indicated that extremes in energy use greatly influence building energy performance.

Kim and Srebric [42] used data from three buildings (two campuses and one office buildings) to investigate the occupant's impact on energy consumption in Philadelphia, USA. Aggregated and sub-metered electricity data were taken from facility managers and two sensors (IR thermal and video-based sensors) to obtain occupant data. A linear regression analysis was performed on the collected research data. The results demonstrated a strong correlation between electricity consumption and occupancy rates. In order to define the motivating elements of energy use in an office building in Trondheim, Norway, Djuric and Novakovic [43] used data from the building energy management system, data related to energy utilization for heating, and the entire electricity consumption from the company's database. For data analysis, the authors deployed regression based on partial least squares and principal component analysis. Results indicated that operational parameters influence the utilization of heating energy in an office building more than outside temperature. In [44], Lu *et al.* implemented statistical and correlation analyses to analyze the energy intake of 27 office buildings, distributed among three cities of Inner Mongolia (i.e., Wuhai, Ordos, and Bayan Nur). The data from these offices were collected through site investigation and on-site measurements. According to the results obtained, reducing energy consumption for air conditioning, and optimizing the number of air conditioning zones are key factors in enhancing energy efficiency. Yuan *et al.* [45] conducted a survey to define the effective elements for energy consumed by 24 office buildings in Qingdao, China. Correlation analysis was used to identify factors influencing energy use. Results revealed that factors heavily influencing energy consumption included residence density and cooling system type. Other elements contributing to energy consumption, such as the number of floors in a building, its age, and heating source type have variable impacts on building energy consumption.

Zhou *et al.* [46] piloted a study to investigate the energy usage of lights in Beijing and Hong Kong office buildings. The study was focused on buildings with large office sizes. The study involved collecting field data from 15 buildings where energy sub-meters were installed to record the lighting energy consumption of each building. Statistical analysis was performed on the collected data, and findings showed that the occupant schedule was the major determination of light energy usage. In [47], Hongting *et al.* inspected energy consumption of 119 surveyed buildings (99 office type buildings, 11 hospitals and 9 schools) in Northern China. In this study, data collection was through surveys, while data analysis was conducted by eQUEST. The results showed that building envelope, air conditioning, and lighting were the greatest factors influencing energy demand. These studies of energy use in commercial and institutional buildings indicate a diverse, vibrant, and well-designed body of survey data.

A summary of the important factors impacting energy consumption in the urban sector (residential, industrial, commercial and office buildings) is presented in Table 2. As shown in Table 2, there are 11 significant factors found to affect energy consumption in urban regions. Four factors, i.e., ''Age'', ''Climate'', ''Education Level'', and ''Energy Tariff'' are found to affect residential buildings but have no correlation with the energy consumption of other building types (i.e., industrial, commercial, and office buildings). By comparison, there are 7 significant factors affecting the energy consumption of industrial, commercial, and office buildings in urban regions. ''Lighting'' and ''Financial hindrance'' are two factors affecting energy consumption by industrial, commercial, and office building that have little correlation with energy consumption by residential buildings. Finally, 5 significant factors have significant correlation with energy consumption of both building categories in urban areas (i.e., household/occupant size, occupant behavior/schedule, air conditioning/cooling systems, awareness/motivation, and equipment/gadgets utilized).

B. THE RURAL SECTOR

Rural communities in different regions in the world contribute significantly to energy, and in particular to electricity demand in ways that are sometimes underestimated. The rural electrification movement in the early 20th century has led to increasing grid connectivity, decentralized systems, and renewable energy generation. In some regions these processes are accelerating. Understanding rural energy supply resources, energy consumption patterns, and factors contributing to energy use in the rural sector is thus essential. These topics have been well explored in the literature for countries such as in Bangladesh [6], China [48]–[52], and India [53]. Most studies are on different types of energy sources in addition to electricity, but only households are identified as the dominant subject of energy consumption research in rural areas. In this section, an overview of that research is provided with an emphasis

TABLE 2. Significant factors that impact energy consumption in urban regions.

Factors	Residential Buildings	Industrial, Commercial and Office Buildings
Age	✓	
Household/Occupant size	✓	✓
Climate	✓	
Occupant behavior/schedule	✓	✓
Air conditioning/Cooling system	✓	✓
Lighting		✓
Energy tariff	✓	
Financial hindrance		✓
Awareness/Motivation	✓	✓
Education level	✓	
Equipment/Gadgets utilized	✓	✓

TABLE 3. Main sources for rural energy demand.

Electricity
Coal
Biomass
LPG
Crop residuals
Firewood

on data-driven research in China, which is particularly well represented in the literature.

In an area near Beijing, China, Li *et al.* [48] studied energy sources and energy consumption of households in Zhangziying Town. The sample size of the study was 208 households. These households participated in a questionnaire-based survey. Statistical analysis was performed on the questionnaire data, and results showed that electricity and coal were the greatest types of energy used. Miah *et al.* [6] collected survey research data from 120 households in different villages of Bangladesh to study energy consumption patterns and factors that influence it. The process of survey data collection was based on personal visits. The analysis showed that differences in income, family size, housing types, and educational status affected household energy consumption patterns. Despite these differences, most families used non-commercial biomass energy. There was less demand for commercial fuels due to their high cost and unavailability. In [49], Zhang and Guo collected research data from ''China Statistical Yearbook'' for a selected year as well as from ''China Energy Statistical Yearbook'' for nine years to determine factors that had an effect on Chinese rural residential commercial energy consumption. A Log Mean Divisia Index (LMDI) method was used in this study. Results showed that the rural residential commercial energy consumption had increased, and indicated that income was the most effective factor on this growth. Tonooka *et al.* [50] conducted a questionnaire targeting over 200 households on the borders of Xian city located in China. The goal of this survey was to explore energy utilization and air pollutants in the region. Results from the survey were discussed and presented in tables, pie charts, bar charts, and scatter plots. Findings indicated that biomass was the most commonly used fuel for cooking stoves.

In addition, findings showed that income level and energy demand were not correlated. Niu *et al.* [51] found in his survey of Gansu households, Northwest China, that the major fuels consumed were biomass and fossil fuels. The authors in [51] surveyed and collected data from over 300 rural households in 11 villages in Tongwei and Gangu counties in Gansu province, China. A questionnaire-based survey was carried out by Xiaohua *et al.* [52] to investigate the energy consumption behavior of 384 households in Sheyang County, China. One of the results of this Log Mean Divisia study showed that most families favored electricity and LPG more than the other types of energy sources such as coal, and biogas (where straw was found to be the main biomass energy source). On the other hand, Joon *et al.* [53] found that income was the main factor taken into consideration when selecting a cooking fuel. In addition, crop residues, dung cakes, and firewood were the core cooking fuels observed in a study conducted in Haryana, India where research data were collected by questionnaire from 250 households and then analyzed. In summary, rural energy data-based studies involve a diverse portfolio of fuels, and there is a need for future studies on fuel substitution and fuel conservation behaviors. The main sources to meet rural energy needs as per the reviewed works are presented in Table 3, with the note that in most studies of rural areas households use multiple types of energy.

V. WATER CONSUMPTION

Water consumption is an important component of the current and future water-energy nexus due to the coupling between the two networks [1], [2]. The topic of water demand management has the same important role as energy demand management. This section provides an overview of practical studies of urban and rural water consumption data and analysis, as outlined in Table 4.

A. THE URBAN WATER SECTOR

Urban water surveys have been conducted in many different countries including Japan [58], USA [59], China [60], Australia [61]–[63], Brazil [64], and Palestine [65], to name a few. Such surveys have been conducted for a variety of objectives such as promoting water conservation and identifying factors influencing water demand, as described in this section.

In Tokyo, Otaki *et al.* [58] conducted a study to determine the feedback effects of water consumption data on conservation practice. A sample of 246 residents was selected to participate in a survey and asked to provide their water meter

TABLE 4. Summary of reviewed works on water consumption.

Objective of the Water Data Study	Country	Year Published	Reference
Urban residential data analysis			
Determining the impact of feedback on water conservation	Japan	2017	[58]
Examining water conservation motivation on water consumption	USA	2017	[59]
Evaluating water and water-energy issues	China	2016	[60]
Finding the effects of social factors on water consumption	Australia	2013	[61]
Studying the effect of both environmental and water conservation attitudes on water utilization	Australia	2011	[62]
Investigating attitudes toward water conservation	Australia	2008	[63]
Developing residential water demand index	Australia	2017	[66]
Calculating per capita water consumption of buildings	Brazil	2017	[64]
Investigating water consumption	Norway, Canada, Sweden, France, Czech Republic, Mexico, Italy, Netherlands, Australia and Korea	2009	[67]
Determining the influencing factors on residential buildings water and energy demand	Palestine	2017	[65]
Rural areas data analysis			
Examining factors that influence Water Conservation Practices (WCPs) and water consumption	China	2017	[68]
Assessing water consumption from public standpipes	Ghana	2016	[69]
Studying factors of domestic water use	Benin Republic	2010	[70]
Assessing the factors affecting resident's willingness to pay for water services	South Africa	2015	[71]
Investigating water use and household water treatment and storage (HWTS) practices	Malawi, Africa	2017	[72]
Conducting a water consumption study in three villages	India	2013	[73]
Determining factors that influence water consumption	Iran	2006	[74]
Inspecting farmer adaptation behavior during water shortage	Iran	2017	[75]
Investigating irrigation water use on cotton farms	China	2017	[76]
Studying the ability to pay for improved water irrigation service	South Africa	2017	[77]
Investigating local and non-local farmer tendencies toward water irrigation	Saudi Arabia	2017	[78]

readings every two weeks over the course of a 24-week period. Respondents received three different types of information feedback about their water use: actual and mean amount of water consumed; ranking compared with other uses; and positive or negative emoticons. High and low consumers decreased their water consumption when they received emoticons and when their savings results were enhanced, respectively. Maas *et al.* [59] carried out a study to examine the effects of conservation motivation on water consumption in Colorado, USA. Data were collected by telephone surveys and matched with other research data sets to have a total of 119 surveyed households. Participants were divided into groups categorized as environmental and social consumers versus cost and convenience consumers. Principal components analysis, statistical and correlation analyses were performed. Findings showed that the cost and convenience consumers used water more than the environmental and social consumers, as expected, but also that there was no statistical difference between consumers in response to weather or price changes.

To evaluate water demand as well as water-related energy demand in Tianjin China, Jiang *et al.* [60] implemented a correlation analysis with research data obtained from questionnaire surveys involving 504 households. Results revealed that clothes washers and showers had the highest water consumption and water-associated energy demand, respectively (clothes washers were higher in water consumption). In [61], Willis *et al.* conducted a study of the effects of social factors on water consumption in Gold Coast City, Australia. Questionnaire surveys were used to collect data from 151 smart-metered houses. The authors in [61] analyzed the collected data using Trace Wizard and SPSS. Their findings showed that income, house location, household structure, land area, and rain water tank ownership were factors affecting water use. Willis *et al.* [62] investigated the effect of environmental concern and water conservation attitudes on the actual water consumed in Gold Coast city, Australia. Data were collected from 132 residents using water meters and questionnaire surveys. Results showed that water consumption varied with the level of residents' concern. Residents with very high concern (VHC) about the environment and water conservation consumed water less than residents with moderate to high concern (MHC). Randolph and Troy [63] investigated attitudes towards water conservation in a study done in Sydney, Australia where research data were collected from 2179 addresses by telephone surveys. Results indicated that consumers were aware of water conservation and were interested in reducing their water consumption in the future. In [66], Jayarathna *et al.* analyzed survey research data (from a mail survey) using regression analysis to develop a residential water demand index. The study was conducted in Brisbane, Australia where 1214 households were involved in the study. Results showed that factors such as household size, existence of pool, age over 65, and income had robust positive associations with water consumption, while factors such as the availability of a tank for rainwater as well as the average price had robust negative links with water consumption.

Souza and Kalbusch [64] determined the per capita water demand of 30 buildings using data from a questionnaire and a municipal water supply company in Joinville, south Brazil. As would be expected, findings showed that buildings with pools and multi-family buildings consumed more water per capita than buildings with individual water measurement systems and no pools. Findings also indicated that buildings with another water source (wells) consumed less municipal water compared to other buildings. Grafton *et al.* [67] investigated the topic of water consumption in 10 countries. Research data were collected through a web-based questionnaire survey with a total of 1600 households participating in the study. Regression analysis was used to find that households paying for water consumed less water than households not paying for it. Also, results revealed that the household features, such as income, number of people, size, etc., had a significant effect on water consumption.

In the Gaza Strip in Palestine, Enshassi *et al.* [65] studied 19 variables to determine factors influencing not only water consumption, but also water related energy demand of residential buildings. Questionnaire surveys were used to collect research data from 30 organizations. The United Nation Refugee Work Agency, municipalities, water utility and the electric distribution utility participated in the survey. Performing statistical analysis on the collected survey research data led authors to discover that climate change, water-energy conservation awareness, and family size were factors influencing water consumption. While many of these results support expectations about urban water demand, they also help to quantify the relative importance of different factors.

Table 5 summarizes the important factors influencing urban water consumption by classifying all factors into four main groups: structural/physical, socio-economic, attitudinal & behavioral, and institutional & cultural factors. As shown in Table 5, the structural/physical factors include water-use equipment; water use technologies such as "swimming pools", "garden", "water taps", etc.; separated water measurement systems; water leak prevention, etc. These factors have intuitively direct impacts on water consumption as physical/technical factors. In addition, socio-economic factors such as "age", "education", "tariff structure", etc., are found to have impacts on urban water consumption. Survey results also indicated that attitude and psychological factors have impacts on water consumption, especially the level of concern about the environment and water conservation. Finally, cultural and political factors have effects on urban water consumption as shown in Table 5. Based on this review, these four groups of factors should be considered in any water-energy conservation and management research and policy.

TABLE 5. Factors affecting urban water demand.

Structural factors	Lot area, showers, toilet, outdoor taps, dishwasher, gardens, swimming pools, rain water tank, water devices, technical features (including water saving devices, water leakage prevention) [62], [65], [66].
Socio-economic factors	Age, gender, income, education, household size, water accessibility, tariff structure and water pricing, temperature and rainfall, [61]-[63], [65], [66], [69].
Attitudinal and behavioral (psychological) factors	Concern about environment, water conservation awareness and practice; beliefs and behaviors of consumers, [58]-[60], [62]-[66].
Institutional and cultural factors	Political ideologies and concern about water supply [63], [65],

B. THE RURAL WATER SECTOR

Rural water demand is a priority for basic needs in many developing countries, and there are still pockets of rural water poverty in developed countries as well. Rural users have a larger water range of outdoor water uses, from kitchen gardens to animal husbandry and irrigated crop water needs. Many of the latter are supplied by groundwater wells and surface water rights, while domestic water use is increasingly served by rural drinking water systems, the wastewater from which may be treated and reused for non-human contact purposes. Rural water research is further constrained by limited water metering. Water research based on data collection in rural communities was investigated in [68], [69], [78], [70]–[77] as overviewed in this section.

Tong *et al.* [68] considered North China for collecting water use data from 622 households. He selected households in Wei River basin to examine factors that influence Water Conservation Practices (WCPs) and water consumption among males and females. The data collection process was based on a questionnaire (administered in face-to-face interviews). Results indicated that females were more likely than males in applying WCPs. However, females also reportedly consumed more water on average than males did. Kulinkina *et al.* [69] conducted a study to assess water consumption from public standpipes. It was carried out in Ghana and specifically its eastern region where four rural towns were involved. The authors of [69] used data records from water meters, rainfall records, and geospatial data; and then analyzed these data by the following statistics: 1) coefficient of variation, 2) Spearman's rank correlation coefficient, and 3) univariate linear regression. Results demonstrated that the low water consumption in the four towns is inversely correlated with high rainfall (i.e., rain water is used when it is available). In [70], Arouna and Dabbert analyzed survey research data obtained from 325 households in 27 villages in the Oueme River basin of Benin Republic. The target behind the study was to determine factors that affect domestic water use. Seemingly Unrelated Regression (SUR) was implemented for the analysis, and it was concluded that increases in water price would not lead to less water use in that context. Results also indicated that accessibility to water resources, household size, wealth, and the time needed to fetch water were the most significant factors influencing water consumption. To assess satisfaction with water services and explore factors that affect residential willingness to pay for water services. Rananga and Gumbo [71] conducted a study in two villages in South Africa. Questionnaire data were obtained from 314 households participating in the study. Findings indicated that participants were not pleased with present water services, and they were ready to increase payment for improved water services. Another example from Africa is the work conducted by Mkwate *et al.* in [72]. These authors looked at water use practice, and also household water treatment and storage approaches in Nkaya, Malawi. They sampled 204 households from two villages, Njerebji and Phimbi, and collected data using a structured questionnaire. For data analysis, SPSS and Microsoft Office Excel software were used. Findings revealed that shallow water sources and wells are the main sources that most Njerenje households depend on, while in Phimbi village, households consumed borewell water. Moreover, the study also found that many households were practicing household water treatment and storage, such as boiling water and storing treated waterin containers. Hossain *et al.* [73] conducted a water consumption study in three villages in rural West Bengal, India. A total of 93 households from the three villages were involved in the study, and the research data collection process was based on two questionnaires. Univariate, bivariate and multivariate analyses were performed on the collected data. According to their results, summer months showed higher water use than winter months due to a combination of monsoon water supply and heat-related water demand. Interestingly, water intake rates in the three villages were more than the minimum standard rates of the World Health Organization. In [74], Keshavarzi *et al.* conducted a study in villages north of Shiraz, Iran to determine factors that influence water consumption. Survey data were collected from rural households by interviews, and 522 responses were received. Different statistical analyses performed in this study concluded that both the household size and the age of the head of household affect water consumption. Also in Iran, a study was done in rural communities of Sabzevar by Rezaei *et al.* [75] to inspect farmer adaptation behavior during water shortages. A survey was used to collect data from 120 farmers. Results indicated that there was a link between awareness and adaptation behavior. In addition, the study found that there was a relationship between media and farmers' knowledge about water shortage and their activities for water management. Another study of irrigation water use was conducted by Feike *et al.* [76]. That study investigated factors affecting a farmer's irrigation decisions on cotton farms in Aksu-Taim in northwestern China. Survey data from 228 cotton farms were analyzed using regression analysis. Factors such as crop types, farm size, and cropping intensity determined the utilization of drip irrigation. Farms in remote areas and families with low levels of education relied more on wells.

Mudhara and Njoko [77] studied the capability of making a payment for improved water irrigation service in a rural region ''KwaZulu'' in South Africa. 151 irrigators were surveyed, and the Ordinary Least Squares technique was applied to identify factors that affect farmer's ability to pay for improved irrigation service. Those factors included household assets, road conditions, and agricultural training. Aldosari *et al.* [78] conducted a study to investigate local and non-local farmers' perception of water issues and irrigation water use in the Kingdom of Saudi Arabia. Farmers from around 1,800 farms were asked to participate in a questionnaire survey to collect data. Findings showed that local farmers were less aware of water issues and modern irrigation systems than non-Saudi farmers. In addition, it was found that farmers in both groups had knowledge about the importance of sustainable use of irrigation water.

From the aforementioned studies, Table 6 summarizes the important characteristics of rural sector water use. First, the main purposes of water use in rural areas focus on three types of demands: household use, agricultural irrigation, and animals water requirements. Water use for agriculture accounts for most water use in rural areas, and the most important factors affecting water consumption for agriculture are awareness of water scarcity and irrigation system management. For household water-use, a simple list of factors bears comparison with water use in urban areas. That is, there are about five factors that affect rural water use, including household size and structure, water resource accessibility, time of fetching water, wealth, and the age of the household head. Unlike urban areas, there are more diversified sources of water supply used in rural areas including rain water, streams, groundwater wells, etc. Hence, the rural literature reported here indicates a willingness to pay for better water quality and improved water services.

VI. WATER-ENERGY NEXUS

Conventionally, water-energy nexus focuses on the supply side with an emphasis on technical and engineering aspects of water supply. That is, the water–energy nexus links the use of energy to supply water (e.g. through pumping), and the use of water to generate power (e.g., through hydropower [79]. In [80], For example, Pan *et al.* discussed the challenges and opportunities for improving water-use efficiency in the cooling systems of thermal power plants. Various cooling systems in thermal power plants were presented, and criteria for guaranteeing the quality of water feedstock were addressed, along with, appropriate design and operating instructions for

TABLE 6. Water use characteristics in rural communities.

Main purposes of water use in rural areas	Household, agriculture/irrigation, and animals' need [69], [70], [74], [76].
Water use in agriculture	Strong dependence on water-use/scarcity awareness and modern irrigation systems [74]-[76], [78].
Important determinants of household water-use	Size and structure of household, accessibility to water resources, wealth and time for fetching water, age of household head [70], [71], [74].
Diversified sources of water supply	Rain water, streams, groundwater wells, etc. , [69], [72]-[74],
Water quality and willing for payment	Concern on water quality and services, willing to pay for better water supply [69]-[72], [75], [77].

the cooling system. The study results indicated that energy and water use both can be reduced by reusing impaired water for cooling, which helps reduce freshwater withdrawal, water pollution, and associated effects on aquatic life and environment.

In addition, Siddiqi *et al.* conducted a quantitative assessment of water-energy nexus in 20 countries in the MENA region [81]. Water-energy requirements of these countries were analyzed by means of bar graphs. The study showed that water is required in large quantities for oil exploration and for cooling purposes in power generating plants. Energy consumption is required for desalination and waste water treatment. Based on the results from this study, it is suggested that policy-makers need to restructure water demand to reduce the amount of electricity used for desalination purpose. In [82], Howells *et al.* carried out a combined analysis of climate change, land-use, and energy and water strategies. The methodology adopted in this work was a module-based approach in which data were passed between sectoral models in an iterative fashion such that the output of one module is the input for other modules. The iteration process was repeated until convergence was attained. From the results obtained, it was postulated that inconsistent approaches and inefficient utilization of resources arise due to the deficiency of integration in resource valuation and policy-making. M. Tatinclaux *et al.* [83] carried out a study of energy generation from wastewater treatment using a floating air cathode microbial fuel cell. The main idea behind this study was to recover as much energy as possible from wastewater. From the experimental results obtained, it was concluded that the microbial fuel cells could be configured in such a way that organic matter would be oxidized, improving power output from primary settling tanks. In [84], Wang *et al.* studied greenhouse gas emission from groundwater use for the agricultural purpose in China. The work estimated the emissions associated with pumping ground water for irrigation purposes, using data collected from 11 provinces and a rough estimation of emissions in the remaining 20 non-surveyed provinces. The data for the non-surveyed provinces were obtained through a linear regression analysis with the average pump lift as a dependent variable and the groundwater level as an independent variable. Using data available from government sources in 366 villages, a linear regression model with an R-squared value of 0.62 was obtained. The energy required for pumping ground water was then estimated. The results obtained in the study show that groundwater abstraction contributes significantly to greenhouse gas emission. These emissions are increasing and are currently unregulated. Ackerman and Fisher [85] carried out a study of long term scenarios of electricity generation in the western region of the United States. The study evaluated the effect of limiting water consumption and greenhouse gas emissions on electricity consumption. The conclusion of the study revealed that the region's water crisis could not be solved by regulating water-related electricity needs. In [86], Fang *et al.* carried out a linkage analysis of the water-energy nexus in Beijing. The linkage analysis detected factors responsible for direct and indirect utilization of resources and the role each of them would play within the economy. Data were obtained from the economy's GDP, energy and water consumption from the Beijing statistical yearbook of 2007. The results showed that water-energy resources are imported from other cities to support Beijing's economy, thus, transferring pressure on water-energy resources to other regions. Scanlon *et al.* carried out a study on water-energy nexus considering Texas, USA as a case study following the drought experienced in Texas during the year 2011 [87]. Data were taken from the Federal Energy Information Administration (EIA) and Texas state agencies. The effect of the drought on both water and electricity supply and consumption, as well as its effect on power plants, were evaluated. Results showed that power plants were able to adapt to the drought by reducing water run-off and also switching to less water-intensive technologies such as wind turbines. In [88], Vilanova and Balestieri explored the water-energy nexus in Brazil considering the amount of energy required for water supply. Data for the year 2012 were obtained from the National Sanitation Information System (NSIS). The central limit theorem with a significance level of 1% was applied to determine variations in electricity required for water supply. Results showed about 27% of water-energy was wasted in water intensive activities such as industrial water supply, irrigation, etc. Following the switch from the Millennium Development Goals (MDGs) to Sustainable Development Goals (SDGs) in 2015, Weitz *et al.* [89] formulated integrated water, energy and food sustainable goals. In that work, the interrelationship between water-energy was established by screening for interactions between the SDG goals, exploring the nature of those interactions, and identifying nexus targets. Based on this nexus approach, remedies for water-energy problems in Ningxia, China and the water scarcity issue in California, USA were presented.

In addition to thermal power plants, hydropower generation technology can be addressed using the nexus approach. In much of the literature, hydropower is considered a renewable energy source, but it can consume significant amounts of water due to the evaporation from the reservoir surface. Scherer and Pfister in [90] conducted a ''Global water footprint assessment of hydropower'' from data of ~1500 hydropower plants to assess reservoir impacts on water scarcity. That research pointed out that hydropower increases water scarcity globally, and that other effects on ecosystems, environment, land use, greenhouse gas emission, and society need to be considered Zhou *et al.* in [91] applied a water-food-energy nexus approach for optimal water allocation and small-hydropower installation in a case study in northern Taiwan. They found that optimal allocation and installation could enhance energy output while promoting water efficiency and food production. The water-food-energy synergies approach in [91] confirms the benefits of nexus approach related to hydropower. Other research papers on water-energy, water-carbon, and water-food-energy nexuses of hydropower were published in [92]–[94] and [97]. These research papers emphasize the nexus approach to improve planning, managing, and operating of hydropower projects in the context of regional, multi-national problems. However, Larsen *et al.* in [95] pointed out the challenges of data availability for analyzing the water-energy nexus in electricity generation. That research found substantial gaps in the availability and quality of regional and global data. Hence, standardized formats and collection methodologies are needed across datasets and disciplines. Future water-energy nexus studies need an open-access data framework for water usage in the energy sector. The data should also be coordinated and collected at fine timescales and spatial scales, alongside hydro-climatic observations for multi-dimensional modeling of climate, socio-economy and technology.

This review of water-energy nexus studies reveals that there is increasing interest in exploiting the benefits of a nexus approach in the water-energy sectors. However, most studies analyze linkages between sectors on the supply side, focusing on processes of withdrawal/exploitation, treatment, delivery, distribution, recollection, and disposal of resources. The high potential benefits of focusing on the demand side, both for separate water and energy sectors and joint water-energy studies are pointed out in this survey.

In addition, most of reviewed studies concentrated on ''water for energy'' or ''energy for water'' relationships from engineering perspectives. Their findings shed light on saving resources and improving efficiency. This approach limits the scope of the water-energy nexus because only two dimensions of ''water'' and ''energy'' resources are considered, whereas a broader framework of social and political processes should be considered to enrich an understanding of the nexus [96]. Scholars in the nexus field of studies are expanding their perspective to multiple-sectors and multiple-stakeholders to make the water-energy systems more resilient via conservation measures, social equity, and policy innovations.

To this end, some of the most challenging aspects of water-energy nexus studies still involve data collection for multi-dimensional analysis across various sectors, fragmented policies, emerging data technologies, and different sector regulations – not only for water-energy resources, but also for food, land, and environment issues.

VII. WATER-ENERGY CONSERVATION: INSIGHTS AND RECOMMENDATIONS

From the foregoing review, the surveyed literature has established a strong intersection between water-energy consumption. It can be deduced that any attempt to meet increasing water demand causes a simultaneous increase in energy consumption, and vice versa. To minimize the depletion of water and energy resources both individual and joint strategies aimed at optimizing consumption must be identified. Some possible remedies are presented and discussed.

For example, depletion of fresh water resources for irrigation and other outdoor activities can be managed in tropical climates in part by collecting and storing rainwater in reservoirs at high elevations and releasing stored water by gravity during periods of drought, and also by better managing soil and ground water storage. When well-designed and managed, these methods can also minimize pumping costs, erosion, and landscape degradation. Another issue raised in the literature is the correlation between water and energy consumption and income level. Since high income earners have the means of conveniently paying their water and energy bills, conservation may not be appealing to them. A possible remedy to this issue is a proportional billing system where the unit cost of water consumption is proportional to level of income, along with ascending block rates based on use. This could potentially aid in reshaping the water consumption habits of high-income earners. Since low income earners generally consume less amounts of water, their consumption may be pegged to a certain minimum volume of water use for basic needs, with ascending block rates applied to consumption above the pegged threshold. Another issue with the sustainability of water and energy resources is the increasing world population. Policy-makers need to initiate aggressive campaigns aimed at enlightening the public about the need to adopt conservation measures on a per capita as well as aggregate population basis.

On the energy end, government policies have limited the deployment of renewable energy technologies, especially in developing countries where regulations exist that large-scale renewable energy sources must be integrated into the main grid. Since micro-grids have become a reliable solution in many regions, government policies should aim to enhance the concept of micro-grid especially in rural settlements. This will aid in increasing the deployment of renewable energy technologies while reducing emissions associated with conventional power plants. Decentralized water and sanitation grids and services bear comparison with innovations in the energy sector.

Energy consumption in rural areas has seen an appreciable increase due to the acquisition of urban appliances in rural settlements. While this acquisition cannot be faulted, sensitization on the need for energy conservation should be initiated in rural communities so that these devices are operated only when desired and not left in operation continuously. High-income households mostly found in urban areas are consuming significant amounts of energy with more electrified equipment. Hence, to enhance energy conservation from the high-income households, a proportional billing system where the unit cost of energy consumption is proportional to level of income may be adopted.

Joint strategies that can be adopted to minimize consumption and optimize the interaction between water-energy consumption include the following. Foremost, domestic hot water needs can be met by a paradigm shift to solar energy technologies. Solar water heaters can be utilized for small-scale hot water needs, while solar powered pumps can be used for groundwater extraction. This will help in reducing energy demand from the utility grid while simultaneously causing a drop in water use and greenhouse gas emission resulting from power generation stations which are majorly operated using fossil fuels and water-cooling systems. Another way of addressing the water-energy nexus is to design cascaded water systems such that the water output of a channel within the system serves as the water input for the next channel. An example of such system is the use of water resulting from the cooling of power plants for irrigation purposes as well as meeting industrial water needs where applicable. In the MENA region where huge amounts of energy are consumed for desalination purposes, water demand of households can be capped with extra charges instituted as a form of penalty for exceeding the capped water consumption to reduce demand, and wastewater recycling can be expanded. Reducing energy costs of wastewater collection, pumping, treatment, and reuse are nexus priorities.

More studies on the water-energy nexus are required to take advantage of data availability from multiple sectors, multiple countries, different types of urban areas, etc. The nexus approach can exploit the benefits of high-technology systems, such as micro-water/energy nexus, smart grids, smart water distribution networks, renewable distributed energy systems, etc. To do that, different time scales for water-energy nexus research are necessary to improve planning, scheduling, operating, and forecasting tasks. Hence, it is recommended that a ''standardized data format'' is necessary for the water and energy sectors that encompasses different scales of time and space. Future projects need to focus more on the demand side of the water-energy nexus. The focus should not only explore engineering aspects of the nexus but also assess the connections between human, social, and political-economy dimensions of water-energy use. A broader framework from political ecology could help locate the water-energy nexus within this broader social context. Finally, there is a need for further study of the interlinks between water-energy at the global level and with parallel research on the water-energy-food nexus, as reviewed in [97].

VIII. CONCLUSION

This paper has provided an overview of the literatures relevant to energy and water data survey research, specifically in urban and rural regions. It provides readers with a comprehensive examination of current studies in the field. Although water and energy research are still largely treated individually rather than jointly, this work provides a review of works in all three areas, and based on that, some insights and recommendations are suggested to improve water-energy conservation using water-energy nexus approach in future surveys The data-based research assessed in this article was conducted by collecting data from databases, surveys/questionnaires, site investigations, and measurements in different communities and household types. Data were analyzed with a range of statistical methods and models. From the energy perspective, survey objectives included studying energy consumption patterns, factors influencing energy use, consumer attitudes, and energy saving actions. From these studies, it can be observed that there is a significant difference in the energy use profile of rural and urban areas. While urban areas rely mainly on electricity, rural areas depend on electricity as well as other energy sources. They contribute to environmental pollution in different paths. From the water aspect, research objectives included studying water consumption and investigating the effect of environment and water conservation behavior on water utilization. As in the energy sector, urban and rural areas have diverse water use portfolios. This overview of energy and water survey research also included data-driven studies that consider water-energy interactions, but those studies are relatively few to date. Most nexus studies focus on supply side issues related to technical and engineering linkages but not on demand side issues related to human behavior, social structure, or political economy issues. Insights and recommendations for water-energy conservation were made that include the necessity for standardized data formats. In these ways, this paper provides a foundation for future survey research on the water-energy nexus.

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