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Smart Rural Village's Healthcare and Energy Indicators—Twin Enablers to Smart Rural Life

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Abstract: Poverty in rural areas remains rife and high despite the rapid societal developments and technological advancements the world is riding on, brought about by the advent of the Fourth Industrial Revolution. Most communities and individuals in many rural areas of the world often face near zero to limited access to basic services such as access to energy and healthcare. The study's objective is to develop linkages between smart rural health indicators and smart rural energy indicators. This is achieved by using a six-stage method developed over a two year period. The method uses sustainable development goals as a point of departure; however, in this study, the focus is on healthcare and energy access. The following indicators has been derived: the number of patients in a village monitored remotely, the number of persons having access to a mobile health clinic powered by a renewable energy source, the number of network routers powered by renewable energy to enable drone usage in a village, and the accessibility of a patient's database by the village surgeon remotely due to reliable and accessible servers powered by a mixture of sustainable and renewable energy. The paper concludes that a sustainable, renewable energy mix acts as the enabling link that renders healthcare services in rural villages accessible to all.

Keywords: indicators; Industry 4.0; rural village; smart rural healthcare; smart rural energy

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1. Introduction and Background

The objective of achieving the 2030 Agenda for Sustainable Development adopted by the United Nations (UN) in 2015 has been affected by the COVID-19 pandemic that triggered global crises affecting healthcare, economy, and the public [1]. The main objective of the agenda was meant to improve human lives while protecting nature [1]. This comprises alleviating poverty and leaving no one behind, including those in rural areas. The agenda does not focus on the selective domains of sustainability but rather embraces all three domains, namely the environmental domain, economic domain, and social equity domain [2]. While current research studies do not seek to take a particular side with respect to introducing definitions of sustainability, they do consider social sustainability to be lacking when it comes to broader definition. The social dimension is emphasized by widely publicized research [3,4], mostly because, as a matter of principle, it moves from the premise of social equity. Most researchers view this as a shift towards equitable access to resources for all [4]. In the current context, access to technological, health, and energy resources comes into play. Technological resources are currently experiencing a radical transformation. Hence, we experience a crossover of what is called the Fourth Industrial Revolution, where the latest digital technologies such as artificial intelligence, 3D printing, telemedicine, etc., have become means and solutions for the world's societal problems [5]. For human development, these extraordinary advances in technology are bringing about a new beginning [6]. Most recently, an observation was made where Industry 4.0 technologies have helped a great deal in the fight against the COVID-19 pandemic and other shared global problems [5]. This is an encouraging development showing that

digitalization can drive the sustainable transformation of society [7]. However, when it comes to determinants, measures, and indicators, there is little evidence on studies in rural regions that analyze factors that influence the growth potential of those regions. [8]. Thus, this article's intent is to develop linkages between smart rural health indicators and smart rural energy indicators. Section 2 covers the research method followed to develop the smart indicator model, Section 3 provides a brief snapshot of the literature review, and Section 4 presents the resulting model and indicator linkages, while Section 5 concludes the article.

2. Literature Review

In the developing world, the problems faced by rural villages range from a lack of basic healthcare to a lack of specialist care mainly due to the link that exists between poverty and disease, indicating that there is a greater burden of disease in rural regions [9]. The results of poverty in rural villages also induce further social inequalities resulting in limited or no access to services, such as portable drinking water, sanitation, and hygiene (WASH) [10]. The services referred to here are crucial in protecting human health in societies in the fight against communicable diseases [11]. As [12] indicates, healthcare is an essential part of life in rural areas as in urban setups. In the same breath, despite the amount of work performed to resolve energy shortages, rural energy poverty remains a stubborn challenge to resolve; hence, when faced with a decision to make choices in energy options, the needs of poor rural people should be one of the critical factors [13]. This segment of the study encompasses a general overview of the guiding literature study. The first section of the literature review defines the rural village in relation to healthcare, succeeded by a discussion on the Fourth Industrial Revolution and smart rural health, smart development and technology, and smart village concepts. The following sections thereafter discusses sustainable development, linking this to sustainable development goals with reference to both healthcare and energy. The discussion on indicators concludes the literature review section. Below is a table that guided the literature search and its themes. In the Table 1, the article's period is indicated for the ease of reiteration.

Table 1. Themes and sources consulted for the literature review.

Articles	Themes	Period	Main Database
Zavratnik, V., et al., 2018 [14], Prause, G., et al., 2015 [15], Visvizi, A., et al., 2018 [16], Kalinka, M., et al., 2020 [16], Shi, L., et al., 2013 [3], Tiwari, P., et al., 2018 [17], Kalinka, M., et al., 2020 [18], Vaidya, A. S., et al., 2013 [19], Huovila, A., et al., 2019 [20], ISO/CD 37122. 2018 [21], Maja, P. W., et al., 2020 [22], Huang R. 2022 [23]	Rural Village, Smart Villages, Cities, Smart Cities standards, Indicators and Healthcare Systems	2013–2022	Sustainability, New Initiative in Agriculture and Rural Development, International Journal of Health Services, IEEE Sustainable Horizon
Irannezhad, M., et al., 2022 [1], Hoosain., et al., 2020 [5], Mhlanga, D. 2022 [6], Renn, O., et al., 2021 [7], Naldi, L., et al., 2015 [8], Kemp, R., et al., 2005 [24], Robert, K.W., et al., 2005 [25], Pellicer, S., et al., 2013 [26], United_Nations 2002 [27]. Mishbah, M., et al., 2018 [28], GA, U. 2015 [2].	Sustainable development, Sustainable development goals (SDGs), Smart rural development, Technology, 4IR	2015–2021	Sustainable Horizons, Sustainability, GAIA-Ecological Perspectives for Science and Society, Journal of rural studies, UN and World Bank
Mars, M. 2013 [9], Bavel, J.J.V., et al., 2020 [10], World Health Organization. 2020 [11], BAKER, S. B., et al., 2017 [12], Demirkan, H. 2013 [29], Appiah-Denkyira, E., et al., 2013 [30].	Technologies, Telemedicine, Rural healthcare, pandemic response	2013–2020	Progress in cardiovascular diseases, WHO, IEEE, The World Bank

Table 1. *Cont.*

Articles	Themes	Period	Main Database
Cecelski, E. 2003 [13], Kammen, D. M. 2015 [31], Cecelski, E. 2002 [32]. Bahaj, A. 2015 [33], Kumar, A. & Rawat, N. 2019 [34], Saroha, J. 2015 [35].	Energy, Poverty, Off-Grid/mini-grids Innovations, non-conventional energy sources	2002–2019	World Bank, New Thinking for Off-Grid Communities Worldwide, International Journal of Energy, Information and Communications
Markowitz, C. 2019 [36], Pfeiffer, S. 2017 [37], Mhlanga., et al., 2020 [38]. Bock, B. B. 2012 [4], Holmes, J 2017 [39], European Commission, European Parliament. 2018 [40], Catarinucci, L., et al., 2015 [41], Chen, M., LI, W., et al., 2018 [42]	4IR and its definitions, IoT in Healthcare, Smart Rural villages/areas. Smart healthcare systems	2012–2020	Int. J. Econ. Finance, European Commission, Future Generation Computer Systems, IEEE

2.1. Rural Village and Healthcare

As [14] notes, there is no existing universally agreed one-size-fits-all proposed definition of a rural village, and this is because the definition always depends on both environmental and socio-cultural changes and structures. It is therefore concluded that communities are dynamic as they are not a "thing" that is inanimate [14]. This applies also for a village or a rural area. Due to demographic change and migration to urban areas, the supply of the remaining population is a problem in more and more regions, and this problem requires solutions to ensure supplies, mobility, and medical care for the elderly population [15]. Even though rural areas and countryside communities have been a subject of concern for policy makers and robust policy frameworks, [16] asserts "village" as a concept and this has arguably been largely absent from the academic literature. This needs to be changed so that a suitable balance between rural and urban quality of life is found [17].

However, [18] uses an example in which coastal villages are dispersed, linearly behind each other, and/or at a greater distance from one another. When it comes to healthcare in rural areas, [3] warns that healthcare specialists such as village doctors and physicians in township hospitals are primary care providers for delivering preventive care and health education for rural residents. These caregivers undertake both health services and clinical services in the village (ibid). Evidently, to continue providing high-quality care to at-risk patients, a solution is required to reduce the pressure on healthcare systems [12]. According to [19], technology and portable devices in healthcare field play critical roles, particularly in rural villages where there are limited healthcare facilities available and due to the fact that deploying medical facilities in these regions is difficult, in contrast to the present developments of medical inflation.

2.2. Fourth Industrial Revolution and Smart Rural Healthcare

The term "Fourth Industrial Revolution (4IR)" or "Industry 4.0" was first popularized in 2015 by the World Economic Forum (WEF). The term became a catch-all phrase used to define impending changes that affect global businesses, worldwide trade, the industry, and models of teaching and learning, emanating from the dawn of "cyber-physical systems" [36]. In the initial stage, the concept was concerned with new possibilities and opportunities of technological advancements in manufacturing but later caused even more discussions and rumbling across all sectors of society [37]. However, [38] posits that 4IR is described as a world in which humans can participate in "moving between the digital domains and the offline reality" as a new way of managing their lives using connected technology. The Fourth Industrial Revolution, as one of the buzzwords, features as a container carrying a plethora of meanings and has become popular as it pops up in almost every setting, including policy arenas [4]. The usage of portable technologies in healthcare systems

has been made possible also by the advent of 4IR technologies [19]. With reference to IoT in healthcare, [12] reports that there have been several related works that previously focused on surveying specific areas and technologies beneficial to the sector. As a result, [5] reported that, most recently, these technologies have been utilized in resolving other societal problems and most notably in the global fight against the COVID-19 pandemic.

2.3. Smart Villages

In their article "It's Not a Fad: Smart Cities and Smart Villages Research in European and Global Contexts", [16] shows the differences that exists between city life and that of the countryside in that the city promises and manifests improved living conditions than the countryside, thereby leading to the fading away of the glamorized view of countryside village life. In developing nations, the increasing cost of healthcare is placing heavy financial stress on its populations [19]. In this view, the concept of a smart village comes up as a unique value proposition that can be employed in a village context to showcase how sophisticated ICT can be beneficial to rural villages [16]. Accordingly, smart villages are "rural areas and communities which can build on their existing knowledge, strengths, and available resources by developing new opportunities", using digital, telecommunication technologies, innovations where "traditional and new networks and services are enhanced by means of better use of existing knowledge bringing rural communities into the future" [40]. This is a future that new villages would want to be a part of in the new era of technological advancements and innovations.

However, [37] asserts that to press forward towards the technological future, a visionary future would require some application of technical skills, knowledge, and calculations. The concept of smart villages is centered around the provision of basic services such as basic healthcare, sustainable energy, access to education, water, and sanitation infrastructure [39]. It is also about advancing basic economic and social developments as key catalysts for ensuring improved livelihoods, basic human security, gender equality, and open democratic engagement [39].

2.4. Sustainable Development and Technology

Sustainable development is very critical for achieving societal development and prosperity [23]. According to [5], the 17 sustainable development goals adopted in September 2015 by the United Nations General Assembly formed part of the 2030 Agenda for Sustainable Development that served as a blueprint that promises a better and sustainable future for all, aimed at addressing the global challenges we face as a society. Sustainable development aims to augment the contribution of knowledge to environmentally sustainable human development around the world as a scientific and technological endeavor championed by the Initiative on Science and Technology for Sustainable Development [25]. This suggests that the endeavor in particular places is focused on deepening an understanding of socioecological systems in particular places while simultaneously exploring innovative methods for producing relevant, credible, as well as legitimate benefits to all role players and decision makers [25].

2.5. Sustainable Development and SDGs Healthcare

Since the new 2030 vison agenda is geared towards the achievement of sustainable growth for all, [5] asserts that SDGs build on the principle of "leaving no one behind". According to [15], the promise that "development" would get rid of poverty in several parts of the globe, especially in third-world nations, remains unfulfilled despite phenomenal advances in science, technology, medicine, and agricultural production [15]. However, the 2030 Agenda for Sustainable Development's most notable contribution in healthcare is its intent to achieve inclusive universal health coverage as well as financial risk protection, access to quality basic and essential healthcare services, and access to safe, effective, and affordable essential medicines and vaccines for all [2].

The literature search in related studies has found remote health monitoring plausible in terms of, importantly, the benefits it provided in different contexts, which amongst them is that it provides convenience for elderly people living in rural areas [12]. The provision of improved access to healthcare for the elderly people in rural areas enable them to live independently at home for longer periods [12]. Having realized that there are deteriorating environmental conditions in many parts of the world, which shows that sustainability might be at risk, [26] insists that sustainable development as a concept has become a widely recognized goal for human society. According to [15], worlds nations need to resolve sustainability problems in a systemically interconnected and interdependent manner [15]. As an example, healthcare and water shortages are one of the key interdependencies to achieve improved lives and livelihood: "Acceptable water quality–Both water shortage (e.g., drought) and abundant (e.g., flood) can contaminate the quality of water by multiple biological and chemical pollutants (e.g., bacteria, viruses, pathogens, and protozoa)" [1]. Generally, poor water quality is inappropriate for human consumption and/or hygiene, presenting immediate health hazards to human health (ibid).

2.6. Sustainable Development and Smart Energy

Today, approximately 17 percent of the global population—which amount to some 1.3 billion people—are without access to basic services such as electricity, and as a result, they depend instead on kerosene and traditional biomass, including dung and agricultural residues [31]. The reality for villages is that energy is not widely recognized as a basic need. In development circles and working relationships, [32] asserts that even between macroeconomists–engineers and other social scientists, there has been very slow-paced action in terms of developing the energy sector in contrast to other sectors, such as health and agriculture [32]. According to [33], access to energy represents a key pillar of development, especially for rural communities. The world has come to the realization that, soon, non-renewable resources extracted from the Earth's crust, such as fossil fuels and nuclear stuff, could be depleted in near future [34].

The above realization is the meaning of sustainable energy has broadened to include the sustainable use of fossil fuels and electricity, which was as a result of the connotation of renewable energy and energy efficiency, as proposed by its early advocates [32]. One of the benefits to take note of with respect to renewables is that renewable energy sources are not at all affected by the rate of consumption as they are continuously renewed by nature [34]. The other benefit that also makes them sustainable and a part of the green technology movement is that they are non-polluting and, hence, considered clean [35]. Both United Nation's Sustainable Development Agenda and Millennium Development Goals have made energy one of the prioritized points and that has been adopted by the U.N. General Assembly [32]. Energy provision is now established as one of the new Sustainable Development Goals, which replaces MDGs after the previously agreed United Nations development criteria were embedded in the Millennium Development Goals (MDGs) [33].

2.7. Indicators

An indicator is a specific sign that shows quantity, simplified observation, and measurable communication characteristics [20]. Indicator developments are valuable contributions to objective settings and a method for clarifying what is important [24]. In a country setting, monitoring regular progress towards achieving the objectives of basic universal healthcare and sustainable development goal targets can be achieved by using indicators [27]. The smart cities indicators standard [21] paved a way forward when it comes to smart indicator developments for villages, because this helps countries implement policies and monitor the progress made. The smart cities indicator standard amongst other things offers the following: facilitates innovation and growth; provides improved services for residents; provides guidance to implementing technologies, smarter policies, and practices that create improved living conditions for citizens; creates conditions where environmental and sustainability goals can be achieved in a more innovative way; helps in identifying the

need for intelligent infrastructures needed by communities; helps in facilitating innovation and growth; and builds an economy that is inclusive, dynamic, and innovative and ready for future challenges [21]. The main reason why selections are made when developing indicators is that no set of indicators can be exhaustive [20].

3. Method

The method followed in this article is introduced and discussed in detail below. The study uses a desktop systematic literature review. The review focuses on previous studies regarding sustainable development goals, sustainability in rural areas, smart cities, smart villages, smart healthcare, smart energy, and smart indicators for improving the lives of rural communities in a sustainable manner. The method is detailed in Figure 1 below.

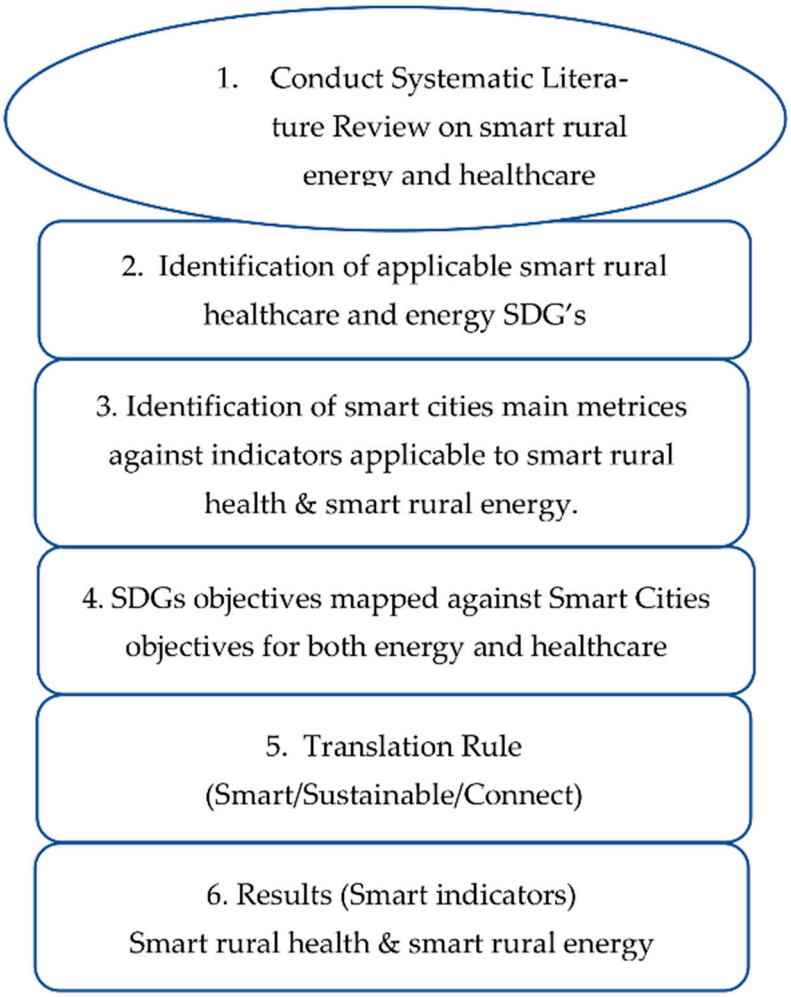

Figure 1. Sequential 6-step indicator-deriving method (adopted from [22]).

As Figure 1 above shows, the method follows a sequential six-step process wherein the initial step is to conduct the literature review, followed by an identification of SDGs applicable to smart rural healthcare and smart energy access and improvements for disadvantaged rural communities. The third step focuses on smart city standard metrices applicable to rural areas that are usable and can be utilized in the current study with a specific focus on linkages between healthcare services and energy in a village. The fourth step aims to map sustainable development goals on healthcare and energy to the objectives of smart cities. The intent is to check whether the same objectives are aligned to rural development and can be achieved in rural villages or not. The last step translates those objectives following

the smart/sustainable and connects the decision rule as previously coined by [22]. Below is a step-by-step detailed explanation of the methodology and results.

3.1. Conducting Systematic Literature Review

The methodological approach followed in this study starts with the systematic literature review. The concepts previously researched and published in the literature are rural healthcare, rural energy, smart rural healthcare, smart rural village energy, and smart village indicators. To achieve the research study's objectives, the University of Johannesburg digital library, IEEE, MDPI, Google Scholar, Springer, and Ebscohost were amongst the reputable databases consulted during the literature search. Figure 2 below is the process flow diagram for the literature search.

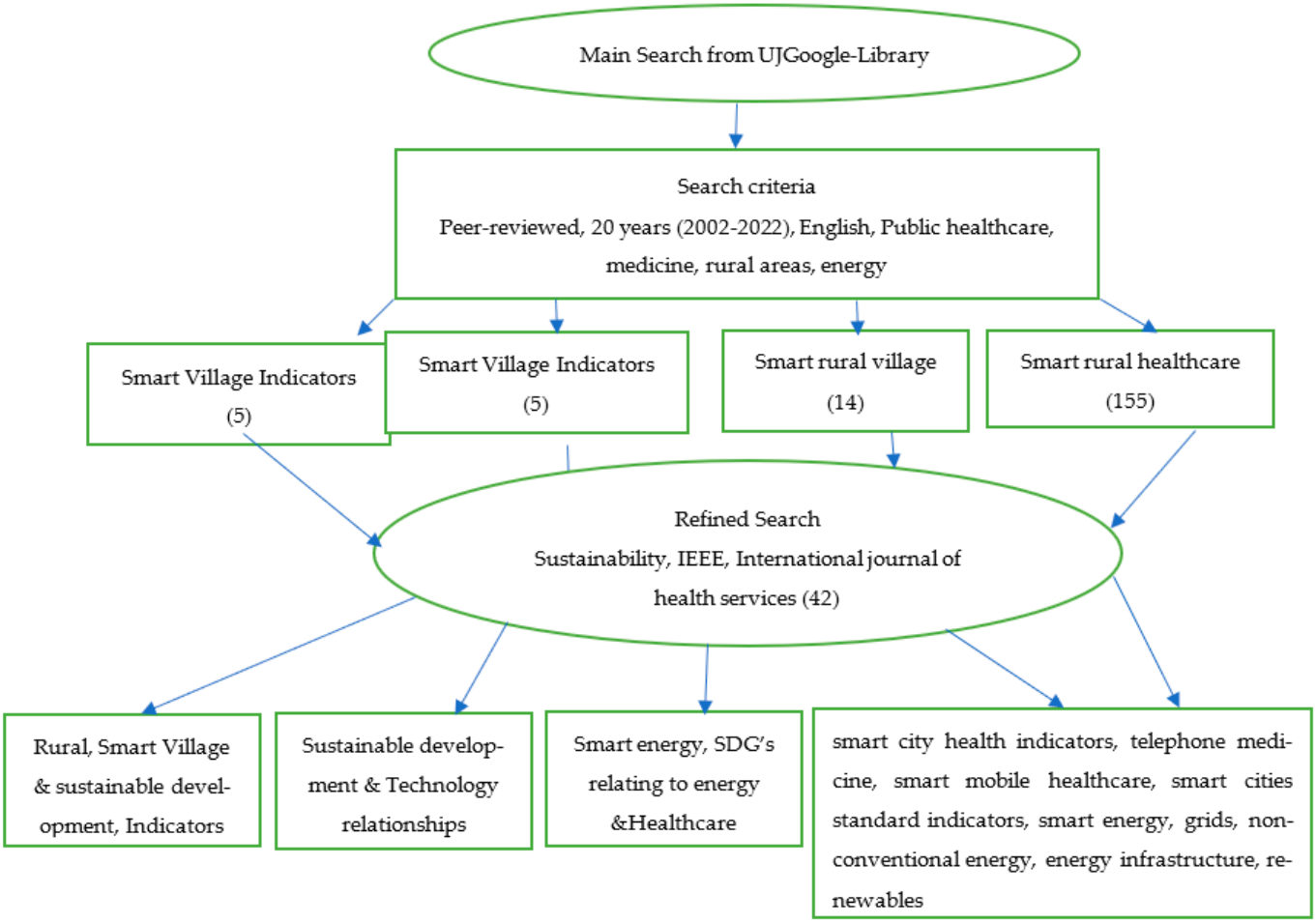

Figure 2. Literature search process flow diagram.

The themes used during the search are indicated on the figure above with number of articles retuned indicated in brackets below the theme. As an example, the smart rural village returned 14 articles while smart village indicators initially returned only 5 articles. The refined literature search settled on 42 peer reviewed articles. All articles were selected based on the English language, and this might be regarded as biased; however, the authors acknowledge this point. While the search concentrated on articles of the past 20-year period, the years ranged from 2002 to 2022, and this does not mean that we completely ignored the buildup to these years. This is purely because most research focused on developing definitions of sustainability as opposed to deriving indicators that are in line with sustainable development goals influenced by Industry 4.0. For reference purposes, we use the below flowchart to show how the systematic literature search was conducted

for ease of replication. To further refine our search process, we investigated journals that concentrate on topics of sustainability, smart rural energy, and smart healthcare systems and indicators with focuses on rural villages. Thus, the following journals were used extensively: *Sustainability*, *IEEE*, *International Journal of Health Services*.

3.2. Identifying SDGs Applicable to Smart Rural Health and Energy

Following the completion of the systematic literature review, the sustainable development goals applicable to the study's objectives are identified and compared against the intended objectives of smart rural healthcare and smart rural energy. To achieve this step, the 2030 sustainable development vision was consulted. The United Nation's (UN) 2030 agenda for sustainable development commitment is that of achieving inclusive universal healthcare coverage as well as access to basic quality healthcare to extend the life expectancy for all citizens while at the same time promoting physical and mental health and wellbeing [2].

3.3. Identification of Smart Cities Main Metrices against Indicators Applicable to Smart Rural Health and Smart Rural Energy

In the third step, the main smart cities metrics on smart rural healthcare and smart and sustainable rural energy are examined for correlations with indicators that would be applicable for the current study. The smart city standard (ISO/CD 37122) is consulted to complete the step.

3.4. SDGs Objectives Mapped against Smart Cities Objectives for both Energy and Healthcare

In step four, the mapping of smart cities' health metric is aligned with the sustainable development goal on health, and then the energy metric is mapped in the same manner. The purpose of the current step is to verify the applicability of the objectives of smart city indicators' standard in relation to healthcare and sustainable, smart energy access for rural villages. As for the energy, the source and the type are critical and would be of interest to verify the linkage and dependability.

3.5. Translation

The translation step breaks down the identified main metric objectives into qualitative metrics. This is so that policy makers in healthcare and energy sectors for rural villages and governments can measure, monitor, or check if the policies they implement achieve the objectives of improving the lives of rural communities. To proceed to the translation, the rule categorizes the measured variables along sustainability, smartness, and connectivity/ICT [22]. According to [28], the core processes involved when developing the energy sector in smart villages is production, distribution, and storage. It should be noted that the best healthcare services require interdisciplinary teams to work together [29]; hence, the basic enabler, which is energy, is brought into the study.

3.6. Results (Smart indicators) of Smart Rural Health and Smart Rural Energy

This step concerns itself with the following questions in order to arrive at final indicators. Will the measured metric/indicator support smartness, sustainability, and/or connectedness of a rural village? Will it advance smartness in healthcare? Would the indicator require ICT infrastructure that is easy to power using renewables and is it sustainable for it to be realized?

When developing indicators in this study, at least two of the requirements are necessary for standardization. It is either smart and connected/smart and sustainable or sustainable and connected. This results in a seven number truth table. It should, however, be noted that smartness and sustainability are non-negotiable. For the ease of decision making on the selection, sustainability is defined as a village's healthcare system that is safe and intended towards bringing long-term benefits for both current and future generations with near zero detrimental effects to human livelihood. Smartness shall mean the ability of a rural village

to build a robust and responsive rural healthcare system to the benefit of everyone in the village in a cost-effective manner through learning and the extraction and dissemination of data or information. ICT/Connectivity is concerned with the needs of a rural village or the capacity of a village to obtain an ICT resource that has the potential to resolve the isolation gap brought by a lack of ICT infrastructure that leads to a digital divide and, therefore, connects rural village communities to the globe to access universal healthcare beyond their rural village borders.

4. Results and Discussion

The following section deals with the achieved results from the Methods section discussed in detail in Section 3. The sequential six-step method was discussed in detail following the graphical representation shown in Figure 1. The envisaged results that would be the resulting rural healthcare and energy indicators linked together stem from the translation method that is also shown in the following sections.

4.1. On Systematic Literature Review

Comparatively speaking, [30] reports that there are several studies that shows that rural residents are disadvantaged when it comes to knowledge about prevailing health systems due to a lack of both the quantity and quality of health services in their areas [30]. The primary issue in rural village healthcare system has always been the need of delivering basic quality healthcare to patients with limited resources, such as nursing staff shortages, while at the same time trying to reduce the cost of such a service [41]. As [42] stated, the collection layer, the transmission layer, and the analysis layer are the three main layers of traditional healthcare systems. This study is interested in the collection layer (i.e., indicators that can be used) for achieving the analysis layer (i.e., for policy makers to make decisions) for smart rural health and energy. The study notes that most rural village populations and undeserved peri-urban populations are off-grid [31]. This refers to areas with little or no access to energy. The UN Secretary General, Ban Ki-Moon, mentioned that "Energy being the golden thread that connects economic growth" has a potential to increases social equity and further creates an environment that allows the world to prosper.

During the search, over 179 articles were returned. They were then refined with the following keywords: rural healthcare, rural energy, smart energy, smart village energy, and healthcare. After refinement, only 42 articles were accepted as relevant for the study. The concepts identified in this study includes smart healthcare, smart city health indicators, telephone medicine, smart mobile healthcare, smart village, indicators, smart cities indicators, smart energy, grids, non-conventional energy, energy infrastructure, renewables, etc.

4.2. Identifying SDGs Applicable to Smart Rural Healthcare and Energy

From seventeen sustainable goals crafted by world leaders on the 2030 vision agenda, we identified goals that are closely linked or goals with a purpose to address health matters for all. We however note that the 17 goals are all linked and can be characterized into three systems, i.e., environmental, economic, and social [5]. Accordingly, the healthcare metric would act as an added advantage to all rural villages to create possibilities of providing access to healthcare and improving the wellbeing of all citizens. SD goal 3 is aligned to healthcare in that it seeks to promote and ensure healthy living as well as the wellbeing of persons of all ages [21]. The authors of [5] insists the SD goal 3 is about the achieving "universal health coverage", which is aimed at increasing the global health workforce in developing countries as well as minimizing pollution-related illnesses and death. Looking at the goal, one then sees that monitoring pollution in air, water, and riverbanks in rural areas would be a positive response.

The goal is further broken down into subsections. For this study, the interest is on goal number 3.d. The goal has a particular focus on developing countries. This goal seeks to strengthen a country's capacity in terms of early warning systems, reduction in risks, and the management of health hazards and risks at both national and global levels [2]. In

that regard, telemedicine, for example, is seen as a means of improving the quality of rural healthcare, increasing access to scarce specialists, reducing the transportation of patients to doctors, supporting rural doctors, overcoming the shortage of doctors, delivering education, and facilitating research [9]. Various companies are working on providing cost-effective healthcare, and some of them are using the idea of mobility to increase user experiences in the field of healthcare [19]. The Internet of Things on healthcare can improve access to healthcare resources whilst reducing strains on healthcare systems and can always give people improved control over their own health [12].

4.3. Identification of Smart Cities Main Metrices against Indicators Applicable to Smart Rural Health and Smart Rural Energy

The smart development of both urban and rural areas must run parallel and simultaneously to maintain the "equilibrium" between the urban and rural areas [8]. Hence, for this section, Table 2 considers the objectives from smart cities and adopts them into smart villages with little modification for "fit-for-purpose" use.

Table 2. Smart city objectives against applicable village indicators and their source.

Metric	Objective [21]	Indicators Applicable/Adapted to Smart Rural Village Healthcare
Healthcare	To provide basic healthcare in a sustainable and consistent manner.	Expectable and dependable general practitioner and other healthcare specialists such as physicians, etc. Does the village clinic have a clear timetable? Which smart energy mix?
		Number of smart mobile clinics per 10K village population: How are they powered?
	To assess the village's knowledge and awareness of online healthcare platforms.	Number of persons registered on and e-health service platform and that are aware of e-health services: Where to put servers and how are they powered?
	To confirm if the village has recreation facilities.	Number of recreation amenities and availability of infrastructure for recreation: How do we enable access during dark hours?
	To determine Village access to fresh, healthy, and sustainable air and harmless drinking water free from excess impurities.	Number of people having access to quality monitoring data for air and clean drinking water: Can they be monitored remotely? How are they powered, and how are data saved for monitoring and evaluation?
	To ensure early warning systems are for the villagers benefits to prevent people from consuming dirty water.	Availability of early warning systems to monitor deviation levels for both water and air quality.
	To ensure people are aware of precautions to take in case of water contamination and responsible water usage.	% No of people with access to clean water (borehole and river). What treatment if any is used before usage because of monitoring result data? Energy source to run the borehole. No. of people in a village with filters installed on main water supply line. No. of smart water meters installed to control usage.

4.4. SDGs Objectives Mapped against Smart Cities Objectives for Both Energy and Healthcare

Table 3 below demonstrates an extract of smart cities' indicators standard for health, with the last column asking which energy source would be used to enable the objective of the indicators. The first, second, and third columns were adopted directly from [21], and for the current study, the linkage of energy is added. The intention is to identify which energy metrics/indicators could be used. The study builds up from a previous study by [22] and groups the indicators in terms of the types of energy before showing what technologies can be used. In essence, the table breaks down the indicators by the purpose for which such energies are used for. As a result, the following logic is followed: sustainability of the energy source; can energy be recoverable to the villager's benefit? Renewable energy, how

can the village deal with the balance between energy supply and demand? How can the village reduce emissions and increase efficiency?

Table 3. Mapping of smart cities' healthcare indicators against the envisaged energy metric.

Metric	Smart City Objective	Indicator	What Energy Metric Can Enable This?
Healthcare	Capacity building for the community system and healthcare professionals to manage diseases nationally and globally.	Percentage of city population that has online medical record files accessible universally to healthcare professionals	Reliable and sustainable energy source to power rural health servers that contains patients' data. Servers can be located anywhere safe with reliable and sustainable energy source. For redundancy, one can be in a city and one in a village for functionality.
	To improve reliability and accessibility of data for researchers (Capacity building)	City's percentage area mapped by electromagnetic-field radiation	Reliable and sustainable energy source to power the EMF equipment
	To present viable options and convenience against the traditional norms in the healthcare sector	Annual Number statistical record (per 100K population) showing medical consultations and appointments conducted online, by using a telephone, or any other online service	Reliable and sustainable energy source to power up communication systems and devices systems and videoconferencing equipment
	To build capacity, and provide early warning to manage health risk to the population	Percentage of city population having access to early warning systems alerts for both water and air quality deviations.	Reliable and sustainable energy source to power up the instruments used for alert systems.

The following questions are raised as a guide to proceed to the next section.

Does the village have early warning systems (to detect water contamination) on their water sources, such as the main village river? How will warning instruments be powered in a village that is not on the main electricity grid?

What is the reliable method of communication in a village for tracking and tracing the village doctor's timetable? How will the villagers know the days and times when the mobile clinic will be stationed at their village? How will the mobile clinic in the village be powered and placed on a communication network?

When coming to recreational facilities, which areas if any are earmarked for community sporting grounds and how well equipped are these areas? Is the facility secured? Does it have proper lighting? What energy source is used to power those lights and other related recreation equipment?

The next section is on the translation method that seeks to resolve the above-mentioned questions.

4.5. Translation Rule-(Smart/Sustainable/Connect)

This translation section uses the following decision rule: smartness, sustainability, as well as ICT infrastructure need. The questions raised in the last section before translation act as guides that are used when cross referencing is performed with the standard for smart cities' indicators. We later check the indicator objectives for alignment against the decision rule that is already mentioned above. This means cross ticking against smartness, sustainability, and ICT needs, as shown in Table 4. The problems facing the developed world of aging populations, a shift from infectious to chronic disease, and the ever-rising cost of healthcare are different to those of the developing world, but they can be partially addressed through the judicious use of telemedicine [9]. Henceforth, for an ease of connectivity, ICT infrastructure is needed in a rural village; as Table 3 shows, for ICT, all indicators are ticked. When approaching smartness, it is our considered view that once the infrastructure is

achieved, the derived indicators would enable the village to be smart in terms of healthcare knowledge and early warning systems that would enable the village to act swiftly to prevent risks while simultaneously having access to healthcare, with their records being available both nationally and globally through online databases or record-filing systems. Table 4 is a result of a build up from Tables 2 and 3, which initially looked at the objectives and, later, indicators applicable to villages. It however expands in a sense that it shows how the translation is performed.

Table 4. Decision rule for smart rural healthcare and recreation indicators [22].

Metric	Objective	Conversion			Smart Rural Healthcare Indicator
		Smart	Sustain	ICT	
Healthcare	To provide basic healthcare in a sustainable and consistent manner.	X	X	X	Expectable and dependable general practitioner and other healthcare specialists such as physicians, etc. Does the village clinic have a clear timetable?
					Number of smart mobile clinics over 10K village population
	To assess the village's knowledge and awareness of online healthcare platforms	X	X	X	Number of persons registered on and e-health service platform and that are aware of e-health services
	To confirm if the village has recreation facilities.	X	X		Number of recreation amenities and availability of infra-structure for recreation: How to enable access during dark hours
	To determine Village access to fresh, healthy, and sustainable air and harmless drinking water free from excess impurities.	X	X	X	Number of people having access to quality monitoring data for air and clean drinking water
	Rik mitigation and capacity building. To ensure that early warning systems are for villagers' benefits to prevent people from consuming dirty water	X	X	X	Availability of early warning systems to monitor deviation levels for both water and air quality.
	Capacity building and management of health hazard in a village. To ensure people are aware of precautions to take in case of water contamination and responsible water usage.	X	X	X	% No. of people with access to clean water (borehole and river). What treatment if any is used before usage because of monitoring results data? No. of people in a village with filters installed on the main water supply line No. of smart water meters installed to control usage

5. Conclusions

This paper has shown that smart rural village healthcare indicators can be derived using a six-step model that takes sustainable development goals as primary support structures and that are enabled through a renewable energy mix. For rural areas to exist beyond the current generation, there must be a way to safely provide access to basic and safe healthcare and preserve the environment and resources for the benefits of future generations in a smart way; the paper concludes that this can be performed by using sustainable, renewable energy as the enabler. This is to say that for a rural village to have properly functioning systems of healthcare, sustainable energy is needed to power the general infrastructure, such as sensors utilized in mobile labs, remote mobile clinics, rivers,

natural dams, and obtaining connectivity to healthcare equipment. The decision criteria, which include smartness, sustainability, and connectivity as cornerstones for smart rural healthcare and access to energy, would provide rural villagers with an option to lead healthy and fulfilling lives. In a way, this presents an opportunity for smart villages to realize development potentials through technological access, receive better living conditions, and become connected to the entire world. The resultant benefit is that the people in these villages would be engaging in a smart rural economy and this can end the skill drain and isolation gap. Accordingly, an opportunity to provide incentives for remaining in rural villages even for young people interested in ICT jobs, health sector jobs, as well as energy sector jobs is presented and seems viable.

The point worth reiterating is that it is not enough to develop a smart rural system in only one area or rural region as an initiative. Thus, the article notes that there is an obvious interaction between different rural systems once such ICT infrastructures powered by non-conventional means and sustainable way exist. A smart rural village system has the potential of improving the utilization of existing natural infrastructure, such as dams and rivers' capacity, by using continuous monitoring. The full utilization of renewable energy to power any sensor and devices used for the villager's benefits should also not be discounted. To expand further as an example, telecommunication infrastructure is needed to make telemedicine possible. Telemedicine needs a sustainable energy supply to power utilized instruments. The recommendation to policy makers is that there is a need to closely look at the linkages between smart rural energy strategies as poverty reduction mechanisms, the provision of healthcare services, and generally to look at renewable energy as an enabler for the provision of basic services to sustain rural areas. As a result, this would not only benefit the healthcare sector but also schools, libraries, etc., meaning the village community at large. The healthcare system is one of the components of the smart rural village system that is dependent on a smart, connected, sustainable, and by extension renewable energy grid that reduces carbon footprints for a better world.

As shown in Table 5, the critical objectives include provisions to basic healthcare, predictable and reliable medical care, access to information (patient's data) by healthcare professionals, capability to utilize the Internet of Things in a village, as well as access to clean water and air.

However, when looking at Table 5's last column, the study enhanced the work of just deriving the indicators by adding the purpose with respect to the energy metric of how these indicators would support the provision of rural village health services. In this regard, we looked at sustainable energy sources, recoverable energy, the village's capability to access and utilize renewables, supply and demand from the national grid and/or standalone energy grid against the village's needs, emission reduction, as well as energy efficiency measures that can be utilized by village communities.

Table 5. Smart and sustainable rural village healthcare and energy mix indicators.

Header	Objective	Key	What Is Needed?	Means/How Will It Be Monitored? Smart Indicators [22]	Means/How Will It Be Supported/Powered? Smart Rural Village Energy Indicators
Smart and Sustainable Rural Village Health	Provision of basic, predictable, and reliable medical care for all.	Access to Health	Predictable GP's Schedule Safe Clinic/Hospital Structure	Community Noticeboard, Automated sponsored SMS reminders, Village Group WhatsApp message reminders. (No. of GP Schedule awareness message communication per annum in a village) (No. of GP's visits in a village per month) Revolving mobile resourced clinics (Number of smart mobile clinics over 10K village population) (No. of nurses supporting the village's mobile clinic)	Number of houses in a village utilizing renewable energy sources like solar panels, gas, wind, and bios as their energy source. Number of community mobile clinics powered through renewable energy sources per country
	Enabling information accessibility: allowing citizens to obtain healthcare information more conveniently on health risks and prevention.	Access to Healthcare Information	Health risk and prevention knowledge	Availability of internet access with zero rated health portal in a village No. of people with access to zero rated internet portal for health Number of persons registered on, e-health service platform and are aware of e-health services No. of people monitored remotely in real terms for physiological conditions (high risk patients)	Number of people connected to the renewable energy grid for ease of access to the internet connectivity via solar powered routers. % No. of households with solar/wind powered smart prepaid meters
	Assessing the villages capacity to receive medication and vaccine using IOT.	Deployment of IoT Systems for healthcare	Smart vaccination in remote areas	Drone usage to deliver medication /vaccines. No. of mobile clinics/village points mapped for receiving medications/vaccination by drones	No. of network routers powered through renewable energy to enable drone usage. No. of mobile clinics powered through renewable energy mix from the local renewable energy source
	Capacity building and management of health hazard in a village. To ensure that people are aware of precautions to take in case of water contamination and responsible water usage	Early warning Systems	Quality monitoring of healthy water and air	Village centralized monitoring system. % No. of people with access to clean water (bore-hole and river). What treatment if any is used before usage because of monitoring results data? No. of people in a village with filters installed on main water supply line No. of smart water meters installed to control usage	% No. of installed street solar powered lights/electric powered for safety in a village No. of solar borehole pumps in a village Number of smart meters in a village powered through a solar energy system

After the paper's literature study appraisal, it is our view that Industry 4.0 brings new hope to rural villages, especially when it comes to the provision of basic services such as healthcare.

It is our considered view that energy is an enabler of these basic healthcare services, which is in line with the sustainable development goals of not leaving anyone behind. We conclude that the indicators derived for healthcare and their linkage to energy has shown that without the linkage, it would not be possible to have smart rural healthcare in villages and even monitoring and evaluation would not be possible. As Table 5 above shows, access to health services (through smart and connected mobile clinics), access to healthcare information (smart, connected databases that are accessible remotely, both nationally and globally), the deployment of IoT systems (e-health, telemedicine, and the deployment of medicine using drones) for healthcare, and early warning systems (smart air/water meters) for rural villages would not be possible unless there are renewable energy sources such as solar panels, gas, wind, and bios that act as energy sources. This is the linkage that shows that energy is the main enabler for these systems. The derived indicators would help policy makers in further developing rural areas in various parts of the globe and can help achieve improved inclusive healthcare for all, as determined by sustainable development goals. The current study is about metrices or indicators that would help in terms of improving access to healthcare and energy as well as showing the linkage for both, with a specific focus on rural areas.

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