Energy Access for Human Progress: Measuring Through an Integrated, Multidimensional People-Centric Approach

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Abstract

Energy access measurements and definitions have evolved over the last three decades regarding various definitional paradigms, frameworks, and methodologies. These paradigms and frameworks have endeavored to define and measure energy access by considering the context of underdeveloped, developing, and developed nations. However, almost all definitional paradigms did not measure energy access through an incomparable matrix or link it to human progress. This paper attempts to address the gap by exploring the interlinking of energy access to the evolutionary and dynamic perspective of human progress and proposes an integrated definition that encompasses both energy access and multidimensional progress. This is achieved through empirical analysis and assessment of various groups of countries from the Global North and South. This paper reviews past definitions and related research across multiple regions, analyzing energy access, resource availability, infrastructure, and progress levels. The findings highlight disparities and identify priority areas for policy action to facilitate an integrated transition toward improved energy access and human progress. This perspective supports global efforts towards an equitable and sustainable future, technological advancements in the energy systems aligning with net-zero emissions targets, and the United Nations Sustainable Development Goals.

Key Words

Energy access, SDG7, Human Development, Human progress, Sustainable development, Equity, Wellbeing

Highlights

a) Energy Access is being measured in an integrated way by linking it to human progress, the position of energy resources, infrastructure, and development paradigms of different groups of countries

b) This paper attempts to address the gap by exploring the interlinking of energy access to the evolutionary and dynamic perspective of human progress and proposes an integrated definition that encompasses both energy access and multidimensional progress

c) Empirical analysis and assessment are conducted on various groups of countries from the Global North and South, examining energy access, resource availability, infrastructure, and progress levels.

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d) The paper identifies disparities and priority areas for policy action to facilitate an integrated transition towards improved energy access and human progress.

e) This perspective supports global efforts towards an equitable and sustainable future, aligning technological advancements in energy systems with net-zero emissions targets and the United Nations Sustainable Development Goals.

Abbreviations

GDP	Gross Domestic Product
HDI	Human Development Index
IEA	International Energy Agency
IMF	International Monetary Fund
KWh	Kilo Watt Hour
LED	Light Emitting Diode
LPG	Liquified Petroleum Gas
MTF	Multi-Tier Framework
NFHS	National Family Health Survey
OECD	The Organization for Economic Cooperation and Development
PPP	Purchasing Power Parity
SHS	Solar Home System
SDG	Sustainable Development Goals
SEforAll	Sustainable Energy for All
UN	United Nations

1. **Introduction**

Since the Johannesburg Summit in 2002, the role of energy in achieving sustainable development has been well-recognized (Bhattacharyya, 2006; Ailawadi & Bhattacharyya, 2006). The primacy of providing affordable, reliable, and clean energy services to the population in attaining sustainable development has been reiterated time and again in various global forums and declarations, though globally, around 600 million people continue to be deprived of access to modern forms of electricity and 2.3 billion people, representing around 38% of the total population, still relying on solid biomass fuels to meet their basic energy needs for cooking (IEA, 2023).

A more explicit thrust on energy as a fulcrum of development has been echoed with the declaration of sustainable development goals (SDGs) by the United Nations (UN) in 2015 (United Nations, 2015). The SDGs, among other things, have explicitly emphasized sustainable energy as the connecting link in achieving many other SDGs. The declaration also states that access to affordable, reliable, sustainable, and modern energy (SDG 7) is critical to the Agenda 2030. SDG 7 is manifested by a set of specific targets spread over three domains, i.e., energy efficiency improvements, scaling up of renewable energy, and access to sustainable energy for all.

One of the targets of SDG 7 is ensuring access to affordable, reliable, sustainable, and modern energy for all. This has an essential interconnection with human development, as previous work clearly shows that energy has a close interconnection with economic growth, which impacts human development. The targets under SDG 7 are further supplemented by several indicators (Table 1).

Table .1 Indicators for SDG Goal 7 on Sustainable Energy

Sl. No.	*Target*	*Potential indicators*	*Indicators under the SE4All framework*
1.	By 2030, ensure universal access to affordable, reliable, and modern energy services.	Urban/rural share of the population with access to reliable electricity for education and modern cooking solutions to reduce indoor air pollution and enhance quality of life.	Access to electricity (percent of population) by rural/urban population Access to non-solid fuel (percent of population) by rural/urban population
2.	By 2030, the share of renewable energy in the global energy mix will substantially increase.	Incremental growth in renewable energy capacity addition to meet energy demand from cleaner sources of energy with a lesser carbon footprint. Compound annual growth rate of renewable energy capacity	Share of renewable energy in total final energy consumption

		addition	
3.	By 2030, double the global energy efficiency improvement rate to promote carbon-neutral economic growth.	Rate of primary energy intensity improvement Rate of energy-efficient appliance penetration	Compound annual growth rate of total primary energy supply to gross domestic product (GDP) at purchasing power parity (PPP)
4.	By 2030, international cooperation should be enhanced to facilitate access to clean energy research and technology, including renewable energy, energy efficiency, and advanced and cleaner fossil fuel technology, and investment in energy infrastructure and clean energy technology should be promoted.	Implicit incentives for low-carbon energy in the electricity sector (measured as US$/MWh or US$ per ton avoided CO_2) Grants, credits, and monetary flows between countries for R&D in clean technology	–
5.	By 2030, infrastructure will be expanded, and technology will be upgraded for modern and sustainable energy services for all in developing countries, particularly least developed countries, small island developing states, and landlocked developing countries, per their respective support programs.	Access to LPG distribution networks Number of rural retail outlets for LPG distribution	–

Source: The World Bank (2015); SDSN (2015)

Though targets and indicators under SDG 7 have been developed in tune with the goal, there have been ambiguities regarding the definition of energy access proposed by different agencies and researchers and its linkages to human development. Human development or progress is about expanding the richness of human life rather than simply the richness of the economy in which human beings live. It is an approach focused on creating fair opportunities and choices for everyone. This novel paper attempts to propose a new framework for understanding energy access from the perspective of Human Progress and then test the framework for different states in India and some selected countries to show how they are positioned regarding energy access in terms of multi-tier development and progress indicators. The novel perspective of this paper is achieved by examining energy access through the lens of human progress indicators, energy infrastructure, and energy resources across developed, developing, and emerging countries.

The paper is organized as follows: The following section ponders upon the relevant facets related to the definitional paradigm of energy access that has evolved over the years and which can also be applied to the core principle of touching upon human development. Section 2 deals with a syncretic understanding of energy access with the "Basic Minimum Needs" framework. Following this, a sense of the relationship between energy access, progress, and development across different groups of countries is discussed in Section 3. Thereafter, it leads to a comparative analysis of developed, developing, and emerging countries in terms of energy infrastructure, energy resources, progress, and development in a spatial framework, followed by a discussion of the way forward toward possible policy implications.

1.1 Defining and Conceptualizing Energy Access

There is no universally accepted singular definition of energy access and, more so, in connection with human development. The idea of access to energy has evolved and differs across geographies. However, it is unanimously recognized that energy access is a means to attain developmental goals, thereby ensuring human development. This may be due to the very nature of energy as a service or commodity, often called an unusual commodity (Boardman, 2012). In the domain of modern energy or electricity, the International Energy Agency (IEA) defines electrification as: "a household having reliable and affordable access (to both clean cooking facilities and) to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average (IEA, 2017)." A limitation of this definition is that if the regional average is low (e.g., sub-Saharan Africa), consumption in countries will also tend to be low and primarily be contributed by urban consumption. To address such imbalance, the IEA has set a threshold of electricity consumption that varies based on the location of the household (IEA, 2018). The UN Advisory Group on Energy and Climate Change describes energy access as "access to clean, reliable, and affordable energy services for cooking and heating, lighting, communication, and productive uses (UN, 2010)." It has elaborated the definition by stating that the levels of energy access should be such that it can develop livelihoods and spur local economic development at affordable prices. The term 'affordable' is relative; the UN definition explains that the energy cost to the end-users should be within their ability to pay and not more than traditional fuels.

However, the above approach to defining electricity access can be considered as reductionist in nature with emphasis on limiting only physical form(s) of access without adequately capturing other crucial dimensions such as acceptability, availability, adequacy, affordability, reliability, and quality of access. Most importantly, the definition of energy demand is derived, and it should have the potential to capture this aspect, too. Further, this conceptualization of electricity access, based on the household-centric approach to defining access, though it appears to be simple to understand and easy to monitor, does not fully reflect the complexity and multifaceted character of the problem that goes beyond the household level into other broader aspects such as the usability of energy, productive use of energy and quality and reliability of supply.

Furthermore, these attributes might also be relative to the quality and reliability that an urban data center may like to have, which might be different from the quality and reliability that will satisfy a household or productive enterprise in a rural area. The traditional counting method is also static and needs to account for evolving technology solutions. For instance, solar home systems (SHS) are usually not considered "electricity connection" in some countries, yet they satisfy the basic electricity requirements of households. Many countries, including India, did not consider SHS installations in their electrification statistics, while some countries, such as Nepal and Sri Lanka, have considered them an electrification option (Palit & Chaurey, 2013). Alstone and others thus presented a framework that conceptualizes the options for gaining electricity access as a continuum of solutions ranging from personal 'nano' grids to SHS to mini-grids to utility-scale systems (Alstone et al., 2015).

The Poor People Energy Outlook, by the Practical Action, thus attempted to address different elements and provided a 'total energy access' framework by recommending that energy access needs should be considered across three major areas: in households, at work, and in the wider community and it also needs to be framed in terms of energy services and not just energy supply (Practical Action, 2010). In this regard, Pachauri (2011) opined that an agreement to define access to electricity depends on three elements based on the consensus of stakeholders. They are (1) different types of services defining the basket of basic needs, (2) the energy consumption threshold of the basic services, and (3) household expenditure on electricity by people from different income groups. One way to understand what energy access means is to consider the incremental level of access to energy services. According to this approach, there may be different energy access levels. The policies for achieving universal energy access can be classified under different heads: (i) electricity for lighting, health, education, and communication, (ii) modern fuels and technology for cooking and heating, and (iii) mechanical power for productive use. Based on the interrelationships between the three stages and for developing robust and inclusive policies, universal energy access can be defined as "access to clean, reliable, and affordable energy services for cooking and heating, lighting, communications, and productive uses."

The Global Tracking Framework of Sustainable Energy for All (SEforAll) attempted to address the gap, i.e., the binary and static access measurement, by providing a more comprehensive multi-tier multidimensional framework that looks at a range of attributes of energy supplies, such as quantity, quality, affordability, and duration of supply, across a range of tiers from 0 to 5 (Bhatia & Angelou, 2015; Groh et al., 2016). It states: "To be meaningful for households, productive enterprises, and community facilities, the energy supply supporting that access must have several attributes: it must be adequate in quantity, available when needed, of good quality, reliable, convenient, affordable, legal, healthy, and safe." Their 'tiers of access' framework recognizes that not all modes of access are equivalent, partitioning tiers – which rank from 0 (lack of electricity in any meaningful form) to 5 (aspirational goal for access) – based on attribute thresholds. It further suggests that the definition of electricity access should focus on the number of customers benefiting from the improved access and the nature and degree of the improvements across the various attributes. Based on this concept, it developed a Multi-Tier Framework (MTF) that offers a tool to measure energy access more objectively by capturing energy access as provided through multiple delivery modes.

Based on the above discussion, it is observed that the historical approaches, which tended to consider electricity access as a typical binary concept meaning "having or not having an electricity connection," have been replaced by the idea that access to electricity cannot be considered a "single-step transition" rather a "continuum of improvements" over a period (ESMAP, 2015). However, it continues to be understood in technical terms, primarily focusing on the "increasing level of electricity consumption over time" without conceptualizing the complex and multidimensional nature of different domains of sustainability and overlooking the interconnection between these dimensions and institutional aspects at local and sub-national or macro level to ensure the sustainability of the solutions delivered.

Several authors have discussed the arbitrary MTF tier thresholds, applying to only two of the six tiers of access (Aklin et al., 2016; Ayaburi et al., 2020; Groh et al., 2016). Jacome and others also focus on the need for more information about reliability experienced by households (Jacome et al., 2019).

Furthermore, while there are approaches, including the MTF, that recognize the importance of adequacy, reliability, quality, affordability, and relevance when defining electricity access (Pachauri, 2011), most often, the tendency is to assume that once the connection is provided, any improvement in access can be made from such provision. It is thus not the question of whether the household is connected; instead, it is whether they are reliably served. However, another study indicates that users might be more interested in whether the appliances could use the energy and the services they made available (Winther, 2008). On this line, the Global Energy Assessment posited access to electricity into two aspects: "the availability of electricity and the availability of improved end-use appliances at an affordable price, with no fixed quantitative targets or standards (GEA, 2012)."

However, some have used the "theory of access to resources" given by Ribot and Peluso (2003) to define access to electricity. According to them, access may be defined as "the ability to derive benefits from things – including material objects, persons, institutions, and symbols." Using this concept, Ahlborg (2012) observes that access to electricity can be meant as "the ability to derive benefits in terms of (a) being connected to the technical system either individually at home or business and getting direct benefits from the use of electric appliances; or (b) having indirect access to benefits through somebody else's use (e.g., a neighbor), or collective services (education, healthcare, electric mills)." The researcher further argued that this definition might also include employment benefits arising out of the electrification as well as the capacity to get benefits from institutions, including from recognized legal structures (like getting monetary benefits for giving the right of way to power lines) and participating in the decision- making process (e.g., member of the village energy committee). Further, there may also be symbolic benefits such as improved social status because of electricity in the house or being part of the local committee.

Despite the different definitions of energy access, as discussed in the above section, an essential element that needs to be added is how energy access can assist in attaining human development, which has so far yet to be included in the definitions and measurements of energy access. Furthermore, the existing literature needs a way to measure energy access through an inter-comparable matrix by linking it to human progress indicators, energy infrastructure, and energy resources across developed, developing, and emerging countries. This paper attempts to create such an inter-comparable matrix for the first time using secondary data sources. Thus, larger complex and interdependent sociological, anthropological, and political factors may have to be brought into the definition.

To achieve the objective, this study, through a review-based analysis focusing on more than 200 papers on energy poverty, definitions of energy access over time, space, and context available from Science Direct, JSTOR, among others, comes up with a syncretic definition of energy access. After that, the paper contextualizes the gaps in the definition of energy access and proposes a new definition of progress within the larger definitional context of energy access linked with human progress. Furthermore, the various components of human progress are identified within the definitional context, and country-specific positions are created using an empirical analysis of the progress of countries based on secondary data sources, viz., the World Bank, OECD, IMF, and other data sources supported by IEA and other databases. Moreover, spatial analysis is conducted for developed and developing countries from Europe, South Asia, Africa, and other parts of the World in terms of access to energy resources and energy infrastructure using the World Bank, IEA, IMF, and Shell database and compiling them into a comparable unit free metric of progress and access to resources and energy infrastructure. The country-specific differential positioning after that leads to prioritized policymaking across various groups of countries. With this premise, Section 2 starts with a syncretic understanding of energy access with the "Basic Minimum Needs" framework.

2. Understanding of the Energy Access through a Basic Minimum Needs Framework

The above approach to understanding access can be framed in the traditional and widely debated discourse on 'basic minimum needs.' The concept of basic minimum needs has been used widely to measure absolute poverty. While the traditional bare minimum needs conceptualization emphasizes food, shelter, and clothing, the advanced and more nuanced approach to ideate basic minimum needs as the basket of goods and services provides opportunities for the full development of individuals (Streeten, 1979). Given the interlinkages between access to energy and human development (Pirlogea, 2012), which is explored in the next section, drawing from Streeten's (1979) arguments, it can reasonably be argued that energy can be considered as part of the 'bare minimum needs' in defining poverty.

However, it further generates the question of defining the metrics to capture 'minimum energy needs.' This is not a new question and has been explored by several previous works. It is argued that a universally accepted set of energy services does not exist, which can be defined as the bare minimum set (Culver, 2017). While there are debates around what constitutes a 'basic energy basket,' it is posited that satisfying essential human needs through access to modern energy requires a minimum amount of energy measured and estimated either in terms of the 'energy poverty line' or in the form of fuel poverty line by employing the conventional poverty measures based on income (Pachauri & Spreng, 2003) or by estimating minimum physical energy requirements. While the 'energy poverty line' measurement primarily relies on income and expenditure data, the minimum physical energy requirement is based on the physical consumption of energy.

In the minimum physical units of energy consumption definition, it is contended that while it becomes easier to include lighting and cooking services, other services such as refrigeration, heating, and cooling do not have a standard, hence very difficult to capture (Culver, 2017). Also, the minimum physical energy requirements per individual or household unit differ significantly across geographies and cultures. For instance, while in Asia and Africa, 100-lumen hours per person per day seems 'satisfactory' (Bhatia & Angelou, 2015), it may not be the same for other developed countries. The IEA also attempted to estimate the minimum physical energy requirement as 50 kilowatt-hours (kWh) per capita per year for rural areas and 100 kWh per year for urban areas (IEA, 2015). Hence, any normative conceptualization of basic needs is subjective and differs across geographies and cultures (Culver, 2017). It is even argued that the minimum threshold for energy poverty will change with advancements in technology and improvements in the efficiency of appliances.

Given the associated complexities in defining energy in terms of basic minimum physical energy requirements, some scholarly work have attempted to estimate basic minimum energy requirements in terms of income spent on energy, often connoted as' energy as an input.' Similarly, others have defined energy poverty thresholds in connection to the threshold income, after which energy consumption does not change with a change in income (Barnes et al. (2011). This conceptualization also has serious problems, as it will differ across regions, urban and rural areas, and income groups. This approach also may not be suitable for developing countries as the underprivileged pay more per unit of energy than the rich (Dutt & Rabindranath, 1993).

Studies conducted in the Indian context show that energy poverty has experienced a sharply declining trend from 1999-00 to 2011-12 (Ranjan & Singh, 2017). However, in the Indian context, no methodology has been adopted to define energy poverty (Schuessler, 2014; Sadath & Acharya, 2017; Ranjan & Singh, 2017). A recent study carried out in the Indian context revealed some interesting patterns that link cooking energy preference and lighting energy preference in connection to income. It argues that cooking energy preference continues to be unaltered until the threshold level of income changes. In contrast, the preference for lighting energy continues to change with every incremental change in income (Ranjan & Singh, 2017).

However, contentions run that the human dimension of energy access and energy use has yet to receive the deserved attention and needs to be adequately captured in the discourses on energy access (Laitner, 2007). Such dimensions must be a critical component of the definition of energy access if we are trying to link access to energy with human development or the progress of society. One way to do that is to create or internalize human development indicators within the definitional domain of energy access. Deprivations caused by energy poverty are manifested through poor human development indicators.

A few research studies have also highlighted the importance of energy access in connection to human development in the broader context of Amartya Sen's capability framework, where energy is considered an essential input for enhancing an individual's capability set (Sen, 2014). In this sense, adequate energy access is prioritized over the quantum of access (Kemmler, 2007). According to this approach, there are two core normative claims: first, the freedom to achieve well-being is a primary moral imperative to attain human well-being and development, and second, the process to achieve well-being must be understood in terms of people's capabilities. To elucidate, people's capabilities must be assessed using real opportunities, or they can do certain activities according to their will. It also must be evaluated in the context of the reasons and purpose that individuals value. At the same time, they exercise specific opportunities to do something within their capability and domain of freedom to do so. This approach has been developed in several specific normative theories; for instance, it has been applied in social justice theories or the normative framework of development ethics. In the Indian context, there has also been implicit recognition that there exists a strong positive correlation between energy use and the human development index (HDI) (Government of India, Integrated Energy Policy, 2006). Even empirical evidence points to the substantial nexus between energy use and human development. Through econometric analysis, Martinez and Ebenhack (2008) established that HDI and energy are strongly correlated, particularly in developing countries. Pirlogea (2012) also shows similar evidence.

The above definitional framework has led to new interdisciplinary work on social sciences measured through new statistics and social indicators. Moreover, it has created a new policy paradigm, mainly used in development studies, through the" human development approach" (Comim et al., 2008). In energy access, this theory is often applied to assess how households make energy choices and consumption preferences concerning the freedom to prefer and attain that choice for achieving human well-being.

2.1 Existing set of indicators for measuring energy access

Existing indicators of tracking energy access for all apply proxies of energy's demand and supply side. On the demand side, the electrification rate is applied as a percentage of the total population's access to electricity. For cooking energy access, the percentage of households using a certain threshold level of fuel for cooking is considered to understand the nature of energy demand. Within the SE4All Global Tracking Framework, the percentage of the population with an electricity connection and those having access to non-solid fuel are broadly estimated through household surveys.

Given the increasing climate concerns, energy access must also be addressed through a process that facilitates renewable energy promotion and energy efficiency measures. At a global level, indicators have already been established to estimate these domains. This includes the measurement of energy intensity through IEA and UN for energy balances. Furthermore, the indicators of energy intensity (e.g., measured through the quantity of primary energy required and measured in terms of tons of oil equivalent) are divided by GDP and sectoral value-added data from WDI (World et al., 2023) to get a sense of energy intensity. However, the limitation of this approach is that it cannot still cater to the value of end-use consumption that can be attempted to be captured through energy-efficient end-use appliance penetration. To capture energy efficiency, the SE4All framework uses the compound annual growth rate of energy intensity of GDP measured in terms of PPP.

Furthermore, the traditional definitional framework on energy access does not fully address the effects of improvement in a device, such as cookstoves, that can provide quality services, reduce air pollution, and help in the improvement of development indicators such as mortality and morbidity rates impacting the indicators of quality of life and at the same time are interconnected to SDG 1 (No Poverty), SDG 2 (No Hunger), SDG 3 (Human Well-being), SDG 4 (Quality Education), SDG 10 (Reduced Inequality), SDG 13 (Climate Action). All these SDGs also define human progress and well-being. Hence, any holistic measure or definition of energy access must touch upon these associated indicators capturing the SDGs mentioned above. Energy poverty has recently been redefined in terms of capabilities deprivation (Day, Walker, and Simcock 2016). Thus, any intervention to bring in electricity (grid or off-grid) will provide avenues for enabling new energy-related capabilities within rural communities.

Therefore, exploring a new indicator-based definitional framework capturing the relationship between energy access, poverty, and progress is critical. It can contribute to human well-being and progress by basing its context on the previous work on human progress. This will provide a more vital context behind the interconnections between SDG 7 and other SDGs by bridging the relationships between energy access, poverty, human well-being, and progress.

3 **Relationship between Energy Access, Poverty, and Progress**

Within the framework of mapping and measuring energy access-related indicators to address the three-pronged relationship between energy access, poverty, and human progress, there is a need to learn from the historical perspective of redefining the journey of progress. One can recontextualize the definition of progress introduced by the San Francisco group on Redefining Progress juxtaposed in the domain of energy access-related tracking framework discourse by first asking the exploratory question, "How should progress be defined?" (Bond, 2006) (Box 1). Once a clear answer and direction arises, further linkages to SDG 7 and other SDGs could be defined accordingly.

Human Progress in literature has been defined through several qualitative and quantitative frameworks. However, each definition has its context setting and can be framed using an equational framework. In the context of this paper, the definition of Progress emerging from the San Francisco group Redefining Progress is incorporated within the paradigm of an integrated energy access is a definitional indicator. Box 1 defines Progress.

Box 1 Definition of "progress"

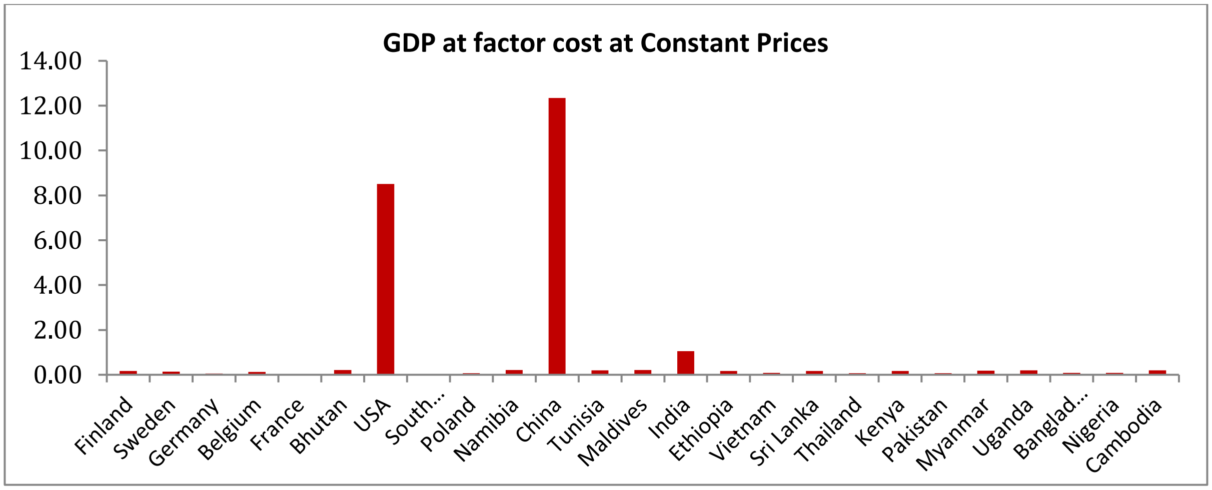
Progress **=** GDP at factor cost in constant prices - the cost of crime and family breakdown **+** household and volunteer work after adjusting income distribution through rewarding equality **-** resource depletion **–** pollution - long-term environmental damage (renewable energy promotion and energy access) **+** opportunities for increased leisure time **+** lifetime value of consumer durables and public infrastructure **-** vulnerability upon foreign assets

Source: Bond, 2006

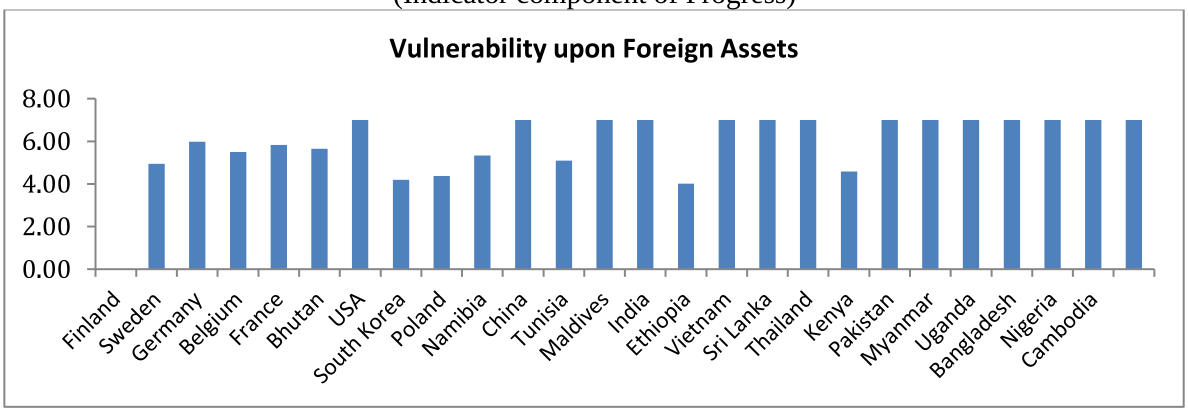
Within the above definition, 'progress' can be seen through the following lenses - a) Economic, b) Environmental, c) Social, and d) Governance in the context of this article. Progress can be necessarily seen through at least these four subdomains as conveyed from the work on progress and development, though more subdomains can also be added. The economic subdomain of progress deals with livelihood, which connects with income, willingness to pay, and asset ownership, adding to an individual's quality of life and well-being. The environmental subdomain of progress is linked to environmental goods and services, which then add to the well-being and progress of a human being. The social domain defines the cultural context in which an individual progresses in the due course of life. The governance subdomain defines the institutional contexts in which an individual progresses and attains well-being in the short, medium, and long term (Becic et al., 2012).

A range of indicators have been identified for each of the following lenses following the progress mentioned in the above equation provided in Box 1. The indicators of these subcomponent lenses of progress for the international level are taken from the World Bank database. The indicators are taken from the Niti Aayog State Level Data through the SDG India Database for India.

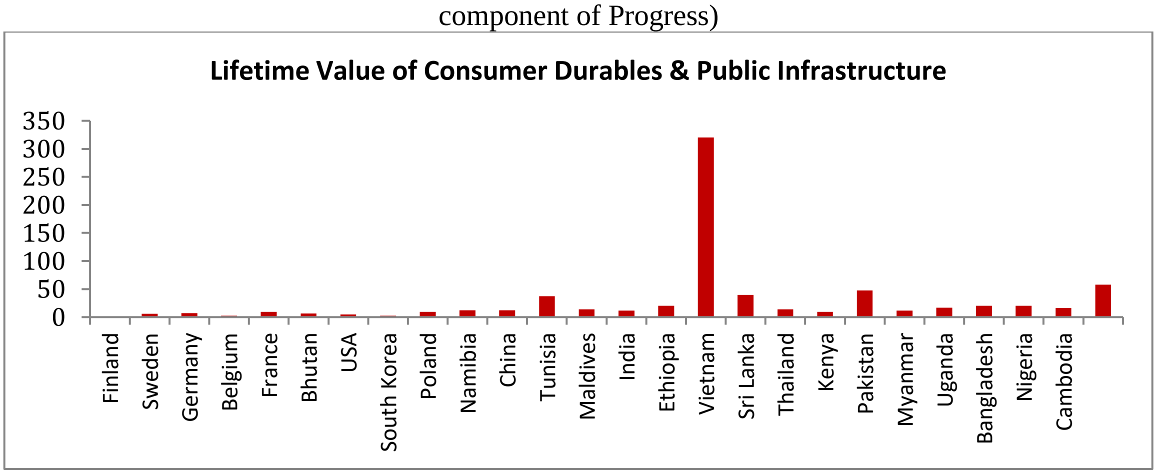
Further, each indicator has been normalized and then standardized, leading to a corresponding Z score. The Z score value of each of the sub-indicators is then incorporated into the "Progress" equation.



Panel 1a: GDP at factor cost at constant prices of developed, developing and emerging countries (Indicator component of Progress)

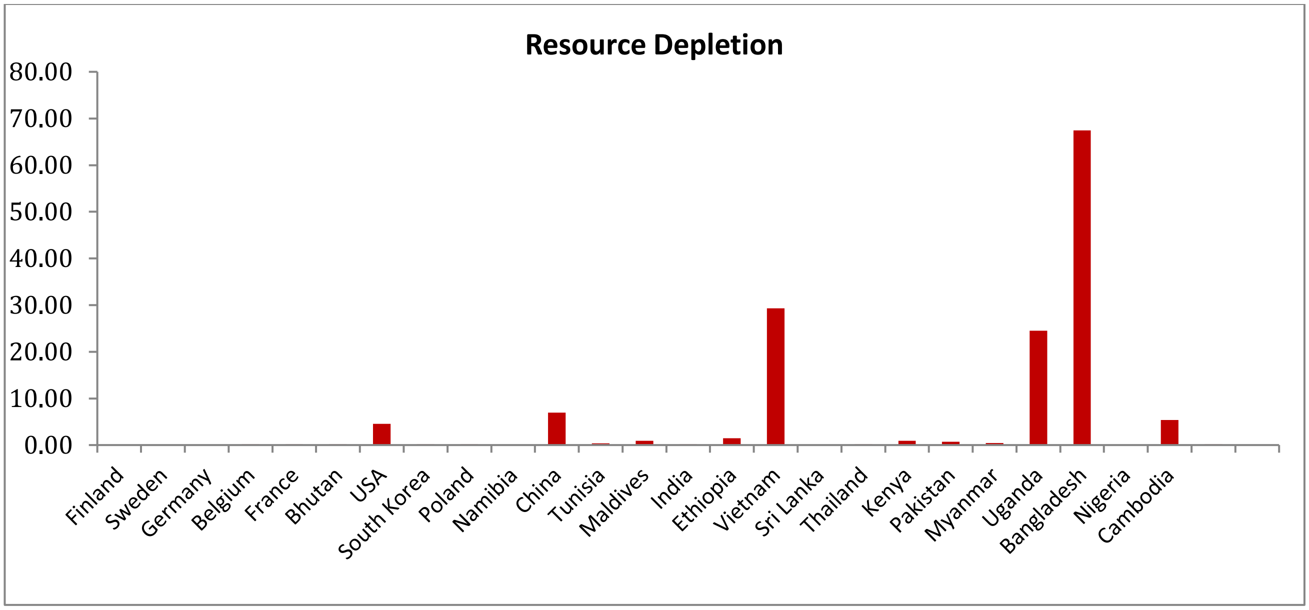


Panel1b: Vulnerability upon foreign assets of developed, developing and emerging countries (Indicator component of Progress)

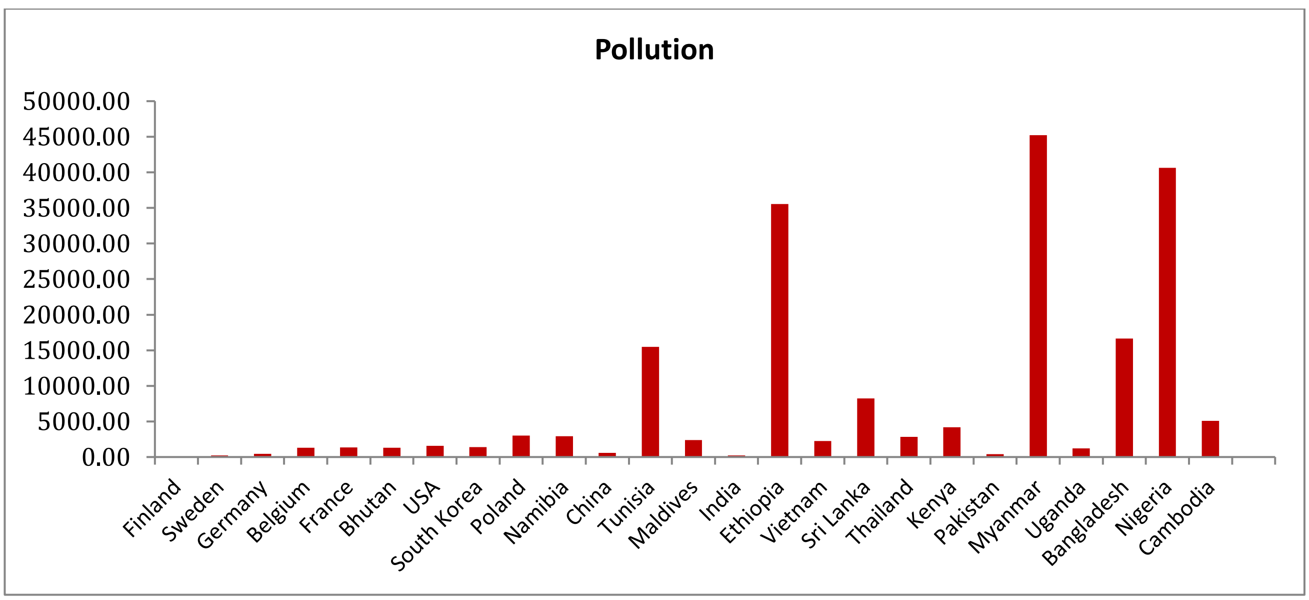


Panel 1c: Lifetime value of consumer durables & public infrastructure of developed, developing and emerging countries (Indicator component of Progress)

Panel-1: Economic Components of Progress (Author's Compilation)

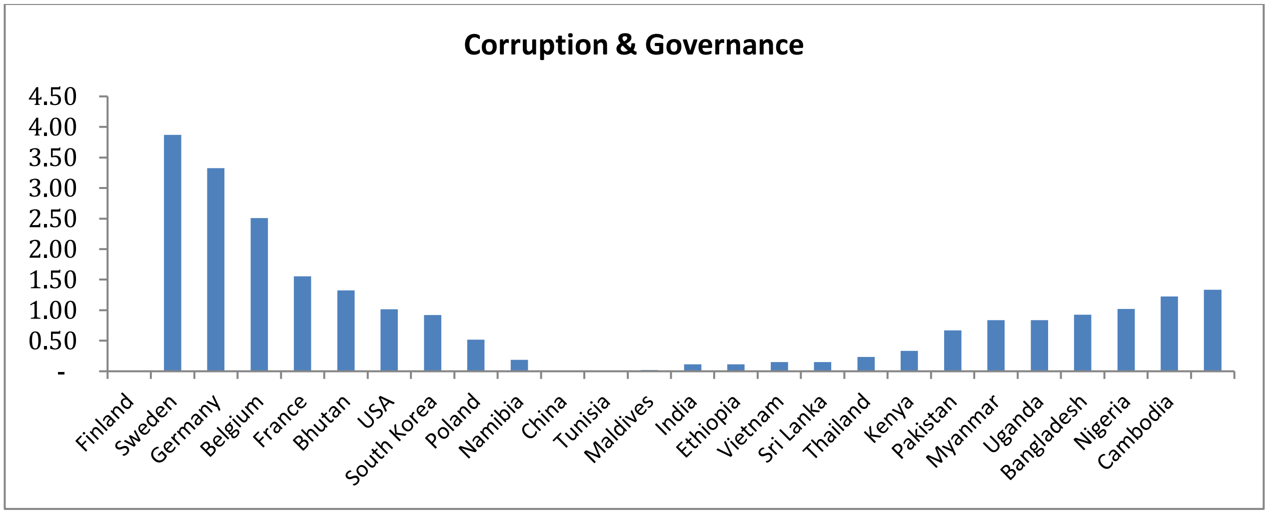


Panel 2a; Resource depletion of developed, developing and emerging countries (Indicator component of Progress)



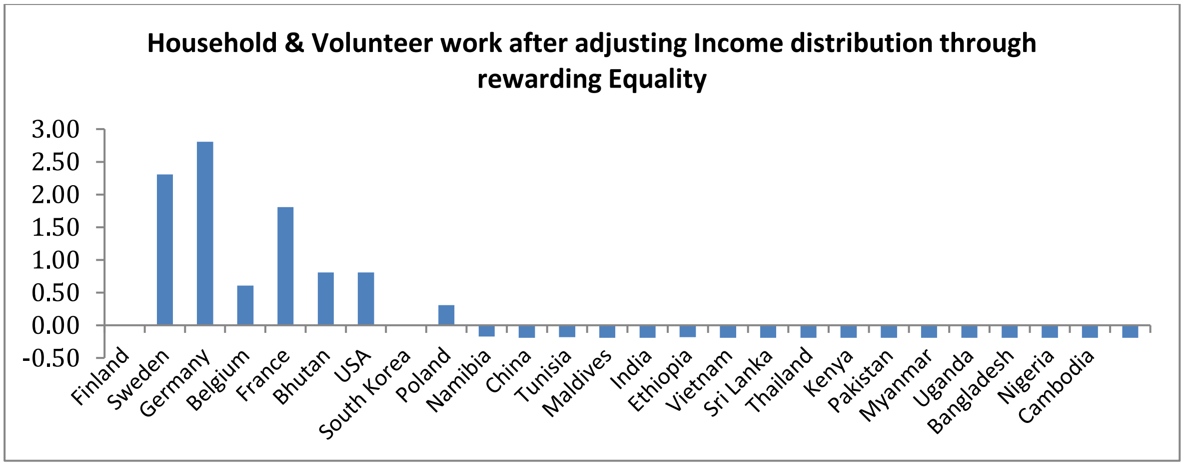
Panel 2b:Pollution of developed, developing and emerging countries (Indicator component of Progress)

Panel-2: Environmental Components of Progress (Author's Compilation)

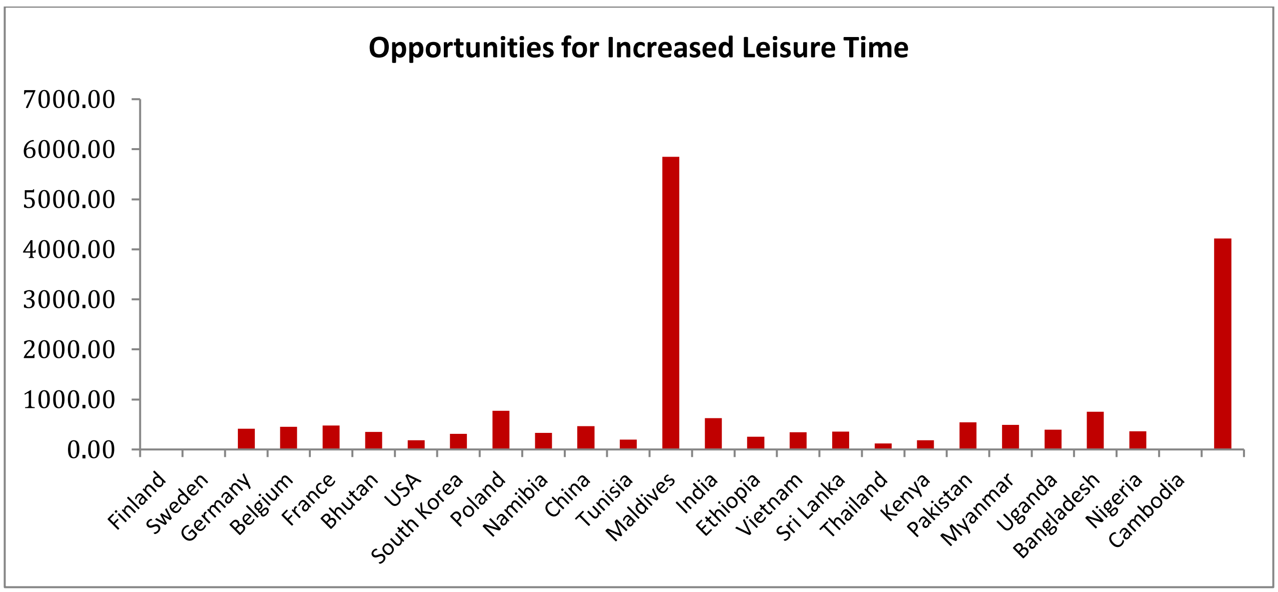


Panel 3a: Corruption and Governance of developed, developing and emerging countries (Indicator component of Progress)

Panel 3b: Gender inequality of developed, developing and emerging countries (Indicator component of Progress)



Panel 3c: Household and volunteer work after adjusting income distributionof developed, developing and emerging countries (Indicator component of Progress)

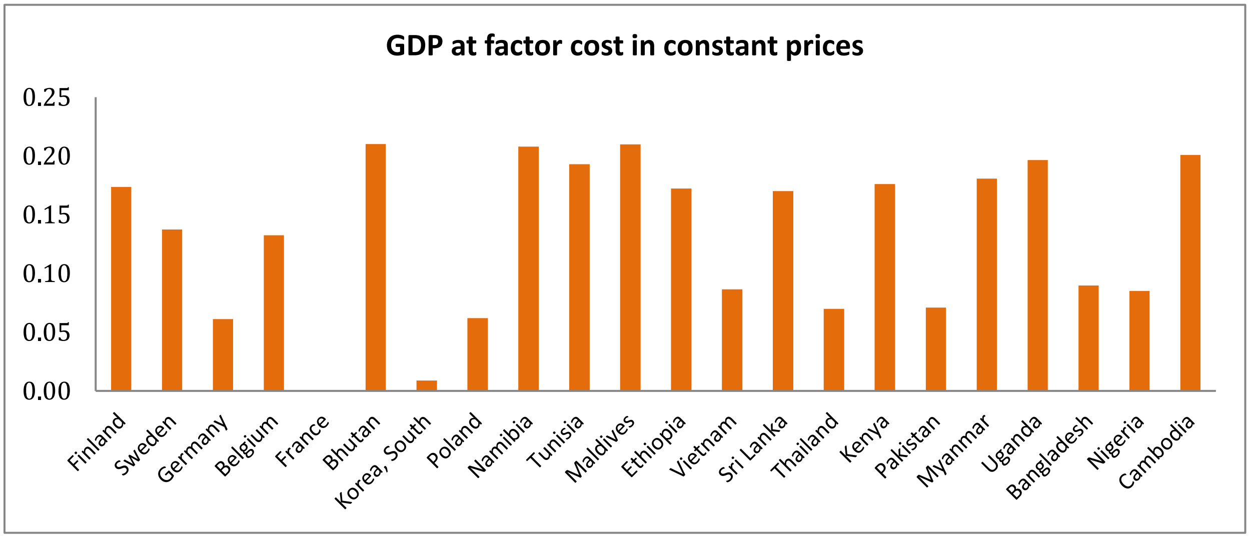


Panel 3d: Opportunities for increased leisure time of developed, developing and emerging countries (Indicator component of Progress)

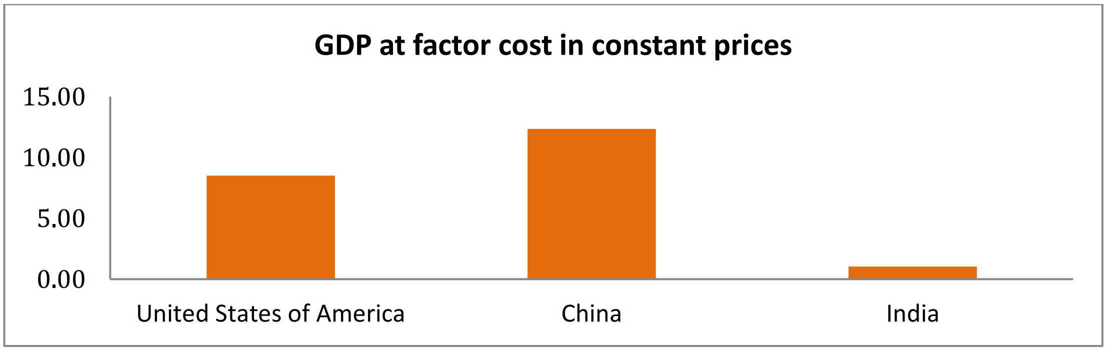
Panel 3: Social and Governance Components of Progress

Panels 1-4 clearly show a differentiated movement in progress's economic, environmental, social, and governance sub-indicators across developed, developing, and least-developed countries. For example, a country like Finland is strikingly doing well in rewarding equality through household and volunteer work after adjusting income distribution compared to other countries such as Poland, China, Kenya, and Bangladesh. Similarly, Finland is positioned much better in addressing corruption through strict institutional and governance measures than other developing countries like Ethiopia, Kenya, Bangladesh, and Cambodia. Even Germany is doing well compared to Ethiopia, Kenya, and Bangladesh, although it is relatively positioned on a lower scale than Finland. Similarly, countries like Finland and Germany are doing much better in tackling environmental pollution and resource depletion, thereby doing better in the environmental domains of progress aided by the support of advanced technology and the availability of financial resources. The size of the GDP at factor cost is also higher in these countries compared to developing and least developed countries like Pakistan.

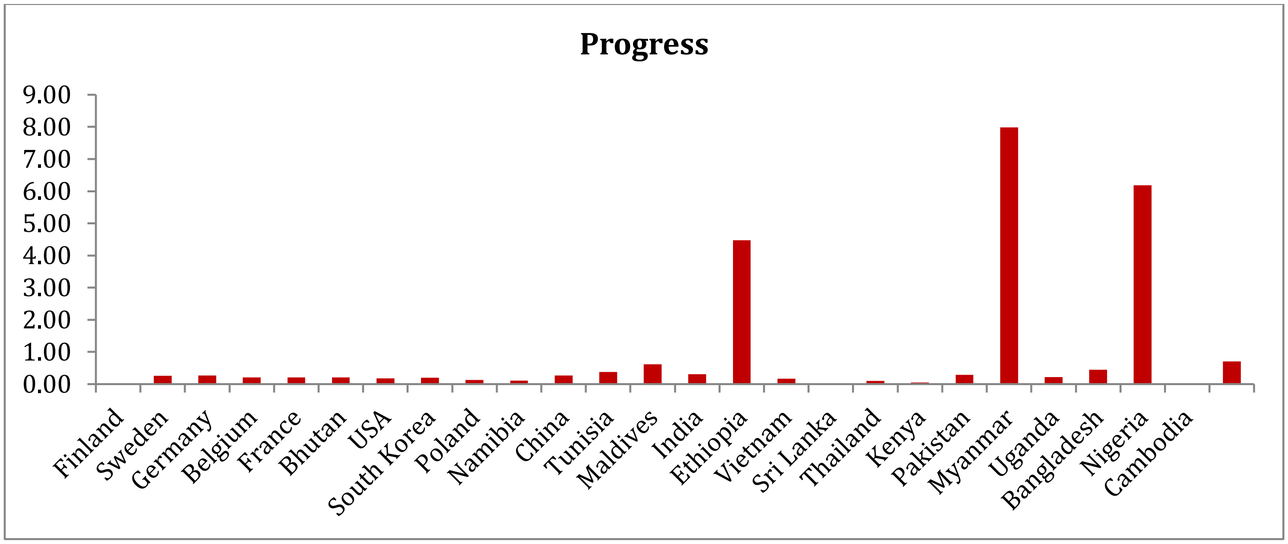
These finally add to the composite value and measure of progress across developed, developing, and least developed countries. When energy access is connected with progress, it is also essential to create an integrated framework of progress with economic, environmental, and social domains of progress. Energy access is connected to economic, environmental, social, and governance domains of progress. Movement in these subdomains can also decide the nature and degree of progress, and in turn, it can impact the energy access situation of countries in a differentiated way. The four panels clearly illustrate the differentiated nature of progress in the varied groups of countries.



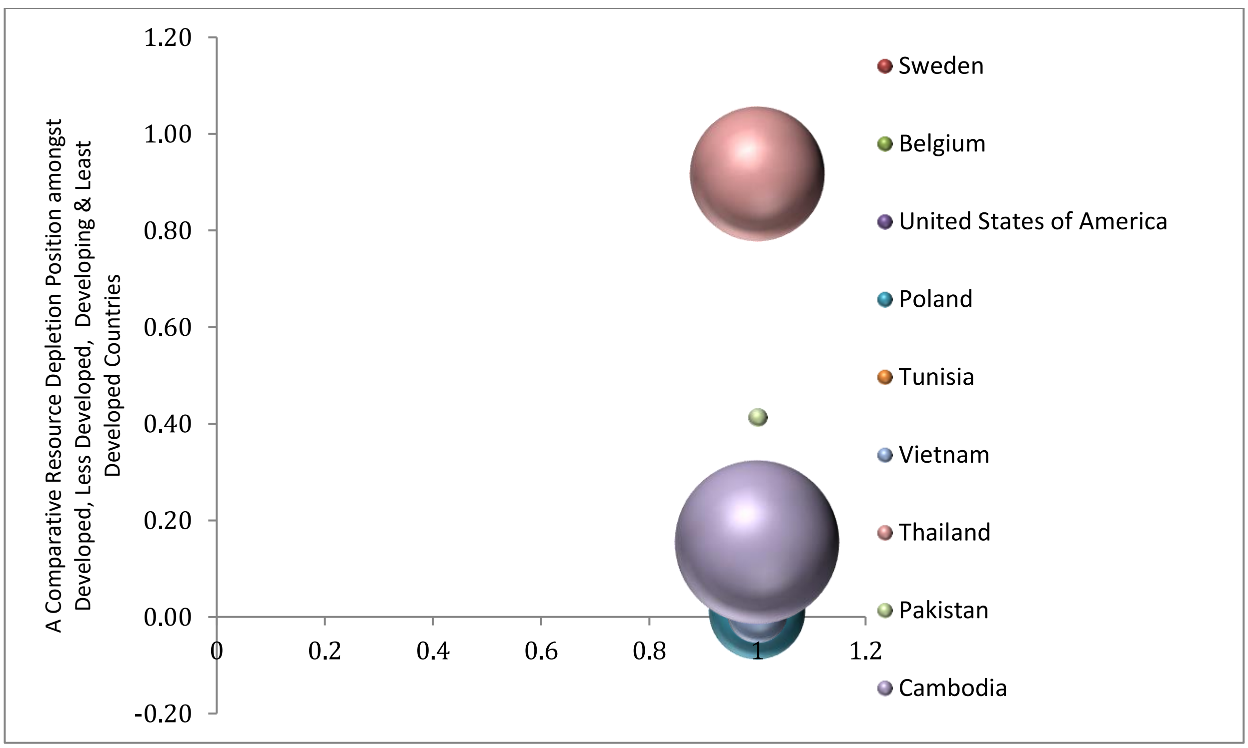
Panel 4a: GDP at factor cost in constant prices of developed, developing and emerging countries (Indicator component of Progress)



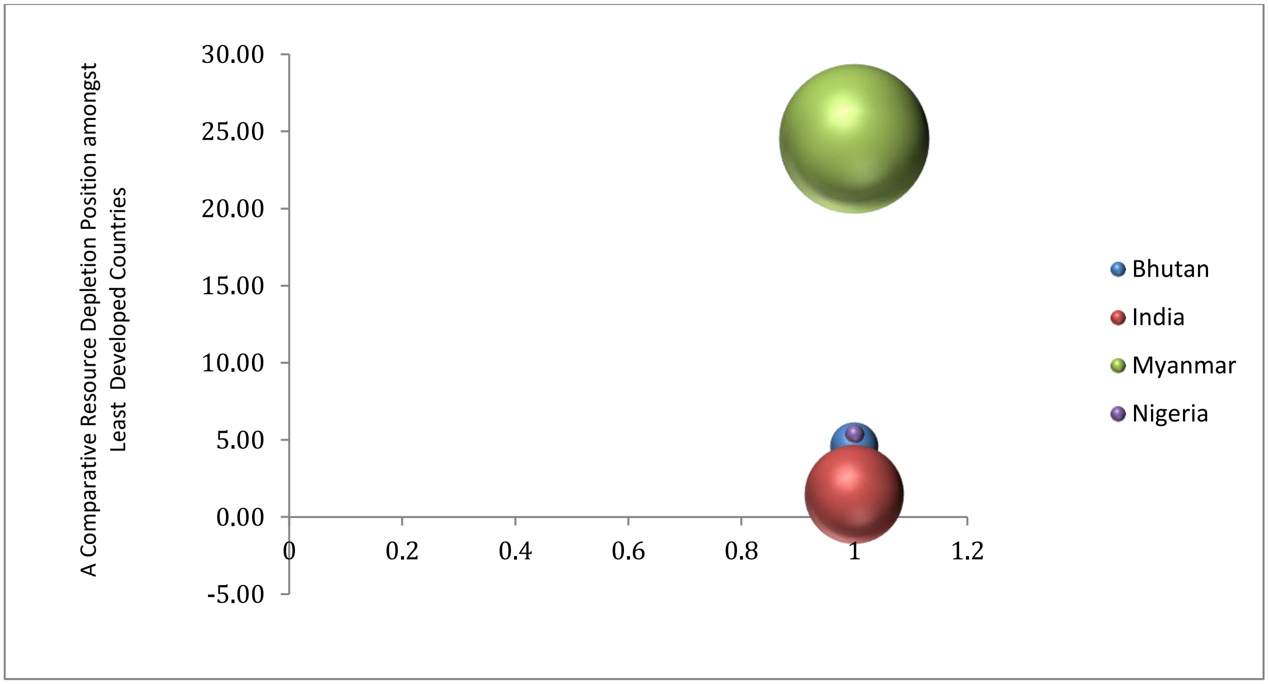
Panel 4b: GDP at factor cost in constant prices of three dominant countries



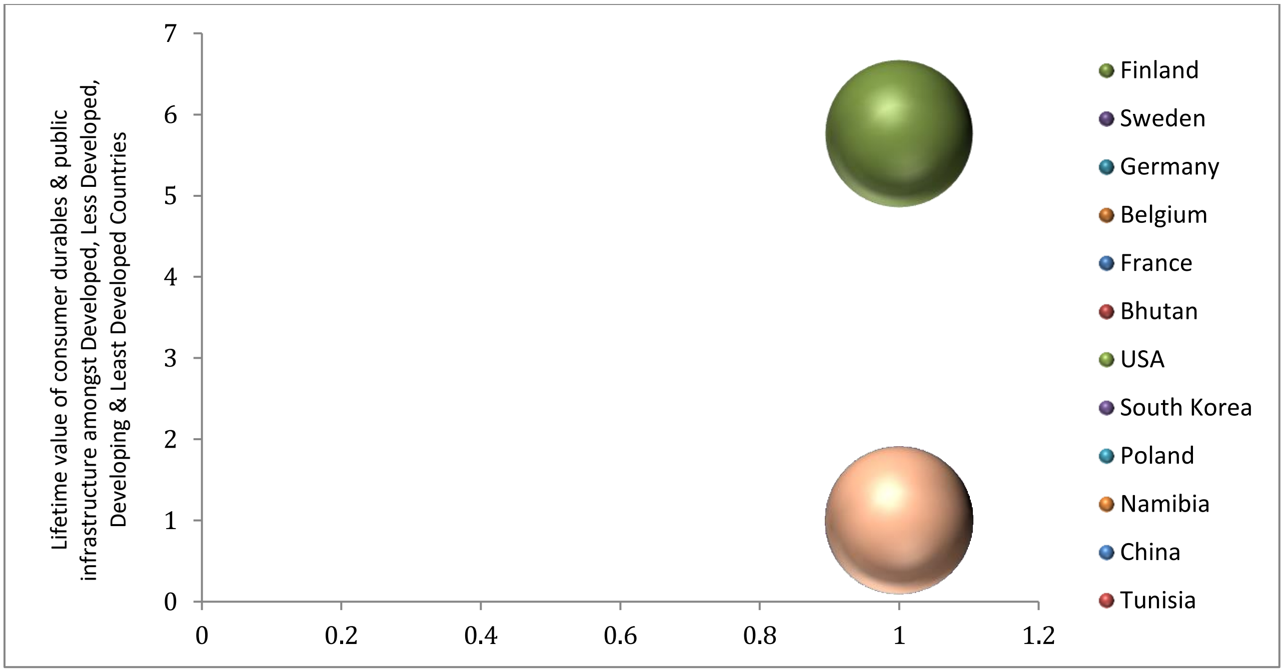
Panel 4c: Progress of developed, developing and emerging countries (Indicator component of Progress)



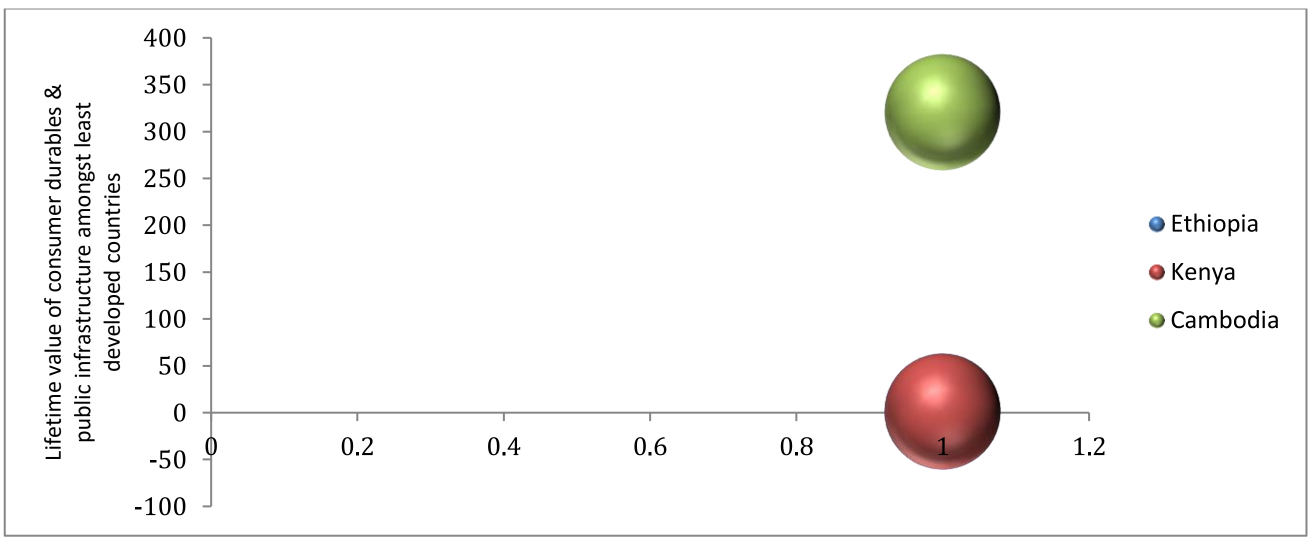
Panel 4d: A comparative resource depletion position amongst developing and emerging countries (Indicator component of Progress)



Panel 4e: Lifetime value of consumer durables & public infrastructure of developed, developing and emerging countries (Indicator component of Progress)



Panel 4f: Lifetime value of consumer durables & public infrastructure of developed, developing and emerging countries (Indicator component of Progress)



Panel-4: Comparative framework of progress across different groups of the country

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Panels 1-4 clearly show a differentiated movement in Progress's economic, environmental, social, and governance sub-indicators. It becomes evident that within the definition of Progress, applied here following Bond (2006), certain variables are already linked to the domain of energy access. Hence, if renewable energy provision and efficiency measures can lead to improved energy access, the long-term environmental damage, resource depletion, and pollution can be reduced. This can translate into a more considerable progress value (in terms of the quantitative mapping framework of Progress) integrated with energy access indicators, thus highlighting the broader connection between energy access, poverty, human well-being, and Progress often measured in terms of HDI.

The global tracking framework tiers in the context of energy access, poverty, and Progress from an energy consumption distribution perspective inequity in energy consumption distribution will have far-reaching consequences in terms of deepening the vulnerability of people who are already in disadvantageous positions and can facilitate further social, environmental, and economic inequalities (Jacobson & Kammen, 2005) and therefore can create a substantial dent on human development and Progress. Energy inequalities often reflect income and gender inequalities, which are present in other developmental dimensions of social welfare and human Progress. More attention should be paid to this aspect of energy discourse.

Recent scholarly attention to this issue, however, reveals mixed results given that there is a differentiation in the nature and degree of Progress across a wide range of countries; energy progress across widely varying countries must also be seen in a differentiated way from an energy policymaking perspective if the primary outcome of energy policymaking is to sustain energy access for addressing the differentiated Progress of various groups of countries.

In the context of the global tracking framework of energy access, which is being used to track energy access and SDG7 under the UN Sustainable Energy for All initiative, and its connection to measure human Progress, the above definition of the energy access-poverty-human progress interconnection gives us a forward-looking direction. Enabling energy access through mainstreaming energy efficiency and renewable energy promotion can produce better human Progress and development outcomes. For instance, more extensive renewable energy provisions for enhancing energy access mean an increase in improved clean energy access to households, thereby generating better health outcomes. Improved provision of energy-efficient appliances and devices (such as higher lumen providing LEDs or electric cooking) can increase clean energy access and allow more people to study with better-quality light or cooked food in a cleaner indoor environment. This can substantially impact human and social capital formation, leading to higher developmental dividends for communities.

Providing clean cookstoves with higher fuel efficiency will also entail better health and developmental outcomes for people, with a rise in their beneficial energy consumption. To illustrate another domain, namely, energy efficiency for addressing interconnections between energy access, poverty, development, and human well-being, one can state that a rise in energy efficiency can create localized benefits in terms of higher energy availability, improved health outcomes, higher energy productivity, rise in GDP, reduction in emissions and poverty, which in a way lead to human well-being and Progress. Lawrence, Liu, and Yakovenko (2013) observed that the energy consumption inequality for 1980–2010 showed a declining trend. On the other hand, in analyzing the energy access and energy inequality trends, Pachauri (2007) found that the overall improvement in the rate of energy access across countries globally (an increase to 75% in 2005 from 50% in 1950) did not commensurate with growth in energy consumption equality. This energy inequality has widened in terms of energy availability in urban contexts. While the global urban electrification rate is around 97%, only 84.5% of the rural population had electricity access in 2021 (IEA, IRENA, UNSD, World Bank, WHO. 2023). Among developing countries, the disparity is more pronounced in sub-Saharan Africa, where the difference between urban and rural electrification rates was as high as 50% in 2021.

The differences in South Asia and Latin America were respectively ~2% and ~3%. Furthermore, in many developing countries, primarily non-poor in urban areas have access to electricity supply, whether grid or non-grid. The Global Energy Assessment report also notes that inequality has been increasing alongside growth and economic development around the World, triggering new development challenges and, therefore, new energy challenges. In several countries where energy access indicators show growth, the poorest segment of the population may not benefit from such growth (GEA 2012).

Specifically, in the case of India, there has been an apparent geographical and income-based divide in terms of energy access. According to the NFHS 2019-21 data, the percentage of electrified households is more than 99% in almost all the states in Southern India and some of the states like Punjab, Haryana, Himachal Pradesh, Uttarakhand in Northern India. In contrast, most states in Eastern and North Eastern India and Uttar Pradesh have less than 96% electricity connection rate. Furthermore, urban or upper-income households consume more electricity than rural or lower-income households (Ramji *et al*., 2012). The former consumes more electricity, even among urban and rural households with comparable incomes. Palit *et al*. (2015) observed that low-income groups use electricity primarily for lighting, whereas increased electricity consumption among upper-income groups can be attributed to appliances and productive use. The CEEW Indian Residential Energy Survey (2020) shows that surveyed households consume 39.3 kWh per month during summer months, and with a 1% increase in hours of electricity supply, household consumption increases by 1.25%. It indicates that for a state like Bihar to enhance electricity access from the current levels to a 24*7 level would mean a 15% increase in the load.

Rural-urban disparities are more pronounced in the context of modern cooking facilities compared to access to electricity. In urban areas, 99.1% of the population resides in households with electricity, whereas in rural areas, this percentage drops to 95.7%. Similarly, adopting clean fuel for cooking shows a stark contrast between urban and rural households, with 89.7% of urban households opting for clean fuel as compared to only 43.2% in rural areas (NFHS 2019-21). Notably, less than 45 % of households use clean fuel in five states, including Bihar and West Bengal. Most households in these states rely on traditional cooking fuels like firewood, dung cakes, and agricultural wastes, thus exposing residents to prolonged health risks associated with pollution.

Danielsen (2012) observes that unequal gender relations limit women's ability to participate and voice their energy needs in decision-making at all levels of the energy system. This situation also has an impact on gender relations and, hence, on human Progress at a household level. While both women and men face institutional barriers to the realization of access to energy as a right, the barriers are encountered in different ways, mainly because gender inequalities are produced and reproduced by energy system governance institutions. Women's right to energy sometimes fails because there is limited recognition of the value of women's work while framing policies (e.g., no economic value is attached to biomass collection by women who undertake it as a household task), and lack of recognition of women's multiple roles (women's work in agriculture and as entrepreneurs is not sufficiently recognized). Govindan et al. (2020) observe that the predominantly "gender-blind" approach towards the potential benefits of electricity access emanates from a reluctance to explicitly acknowledge gender-based differences in needs in creating equitable outcomes. The assumption that electricity access itself is enough for associated benefits to trickle down, that too equitably for men and women, stems from limited awareness. Recognizing the right and multiple roles is essential to define and take forward human Progress.

Having outlined the importance of energy distribution, it is crucial to understand how various countries in different regions fare in terms of access to energy resources, infrastructure, and human development. This understanding is essential because energy access issues are frequently discussed in the context of energy resource constraints or energy security.

3. An empirical and spatial analysis on the interlinkages between energy access, poverty, and Progress.

Human development is essential as affordable, equitable energy access contributes to eradicating extreme poverty and hunger (SDG 1 and 2) through enhancement of livelihoods, agriculture improvements (including irrigation) or setting up of micro-enterprises. Food storage and processing-related energy provisioning through an equitable energy distribution can help meet food and nutritional requirements (SDG 2). Similarly, equal access to energy across different types and classes of rural households can improve health and well-being by enabling the functioning and service delivery of health centers and hospitals (SDG 3). Equitable energy provision is imperative to improve health indicators. Without energy, many life-saving interventions cannot be undertaken, including maintenance of vaccines, the functionality of diagnostics such as X-ray machines, and performing minor procedures and deliveries at night, among others.

On the flip side, equitable provision of clean cooking options across different classes of rural households can reduce the global burden of disease related to air pollution from mud stoves that are responsible for almost 3.7 million premature deaths annually (IEA, 2022). Equitable energy access will also facilitate achieving the goal of universal education (SDG 4) through essential lighting in schools and homes, enabling time for the studies of children. It can also facilitate access to drinking water by energizing pumps and facilitating water treatment options (SDG 6). This will reduce the burden on women and children related to water and fuel collection and cooking (SDG 5). Hence, equitable energy distribution in one go can impact other associated SDGs linked to SDG 7 and the level of human Progress.

However, equitable access to energy is linked to the availability of infrastructure and financial resources and the need to translate these physical resources into usable forms. Providing equitable electricity to 650 million people without electricity connections worldwide will require a cumulative investment of **$33 billion/year**. Providing clean cooking fuel for 2.7 billion people will need a cumulative investment of about **$56 billion** between 2010 and 2030 (IEA, 2010a). This investment support must come from public and private sources complemented by legal, policy, and regulatory support. Given that different countries and regions of the World are contextually placed in terms of energy and financial resources, infrastructure, and human development, a homogenous one-size-fits-all approach will not be pragmatic.

Hence, an empirical spatial mapping exercise is conducted to understand how different regions and countries are placed regarding their human development, access to resources, and infrastructure. This is done by introducing a classification framework to facilitate a more nuanced understanding of the interlinkages between energy-related SDG 7 and other SDGs in varying local conditions.

The framework uses three indicators viz. i) energy resource access, measured through indicators about access to primary renewable and nonrenewable energy resources; ii) energy infrastructure access, measured through indicators about access to electricity and other energy transportation infrastructure; and iii) the status of development, expressed through standardized and normalized UN HDI scores. Access to renewable energy resources and energy infrastructure can generate a range of energy services, which can facilitate the components of human Progress related to resource depletion, environmental pollution, and public infrastructure, as applied in this paper.

Four quadrants are constructed. Quadrant 1 indicates a space of countries with high energy resources and infrastructure. Quadrant 2 belongs to countries with low energy resources and high energy infrastructure, whereas Quadrant 3 caters to countries with low energy resources and low energy infrastructure. Quadrant 4 belongs to countries with high energy resources and low energy infrastructure. The worst-performing countries will lie in Quadrant 3, and the best in Quadrant 1. The intermediate countries lie in quadrant 2 and 4. A country's policy push and incentives should be designed so that all countries move towards quadrant 1 from their respective quadrants. However, each country's nature and prioritized focus in a quadrant will differ due to different contexts. For instance, a country in Quadrant 2 with low energy resources will focus on energy imports. However, being endowed with a good energy infrastructure, it will prioritize energy efficiency measures, which will, in a way, also impact the economic development and the associated SDGs 11, 12, 13 (climate-resilient habitation, sustainable consumption and production, and climate action).

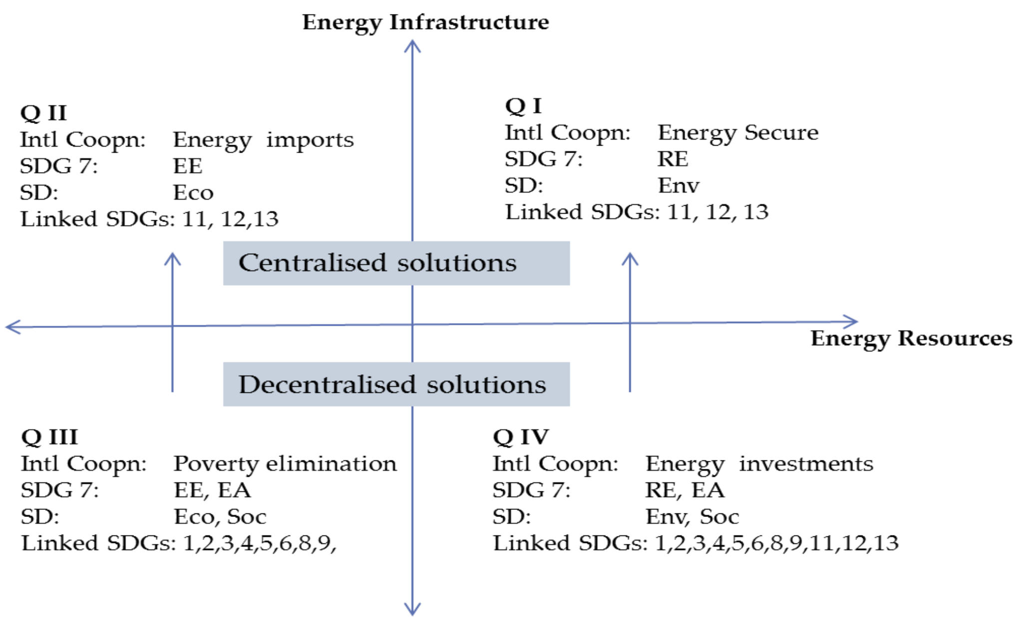

Figure 2: Illustrative reading of the quadrants – Adapted from Srivastava, L. et al. (2018)

EA: Energy Access. EE: Energy Efficiency, RE: Renewable Energy, Eco: Economic Growth, Env: Environmental Protection, Soc: Social Equity

Countries in quadrants 1 and 2 will primarily focus on centralized solutions to create human Progress in the long term by using energy access to attain development. However, countries in quadrants 3 and 4 can move towards decentralized energy solutions. This will primarily happen due to these countries' low energy resources and infrastructure. Policies must be prioritized accordingly in the regions and countries that belong to each quadrant to reach Quadrant 1.

Illustrating this further, one can say that in a region like Europe, which is well-endowed with energy resources owing to its stable imports with a more significant dependence on coal and gas, the prioritized focus areas of SDG 7 will continue to be renewable energy for attaining human Progress. Owing to a high per capita energy consumption and more considerable import of coal and gas, energy efficiency would also be necessary for Europe or developed countries but possibly less in the short term than in developing, emerging, and less developed countries, which will lie in QII and would continue to depend on energy imports to meet their needs. Eventually, with a rise in Progress and development, energy efficiency in developing, emerging, and less developed countries will also gain priority in the long term, beyond the fifteen years.

A region like Europe, albeit sensitive to pollution-related issues in a comparative prioritized way than other regions, would have to focus their policy attention more on inter-linkages between energy and SDGs catering to climate protection, sustainable consumption and production, and sustainable cities in the short-term span of next five years (Figure 3).

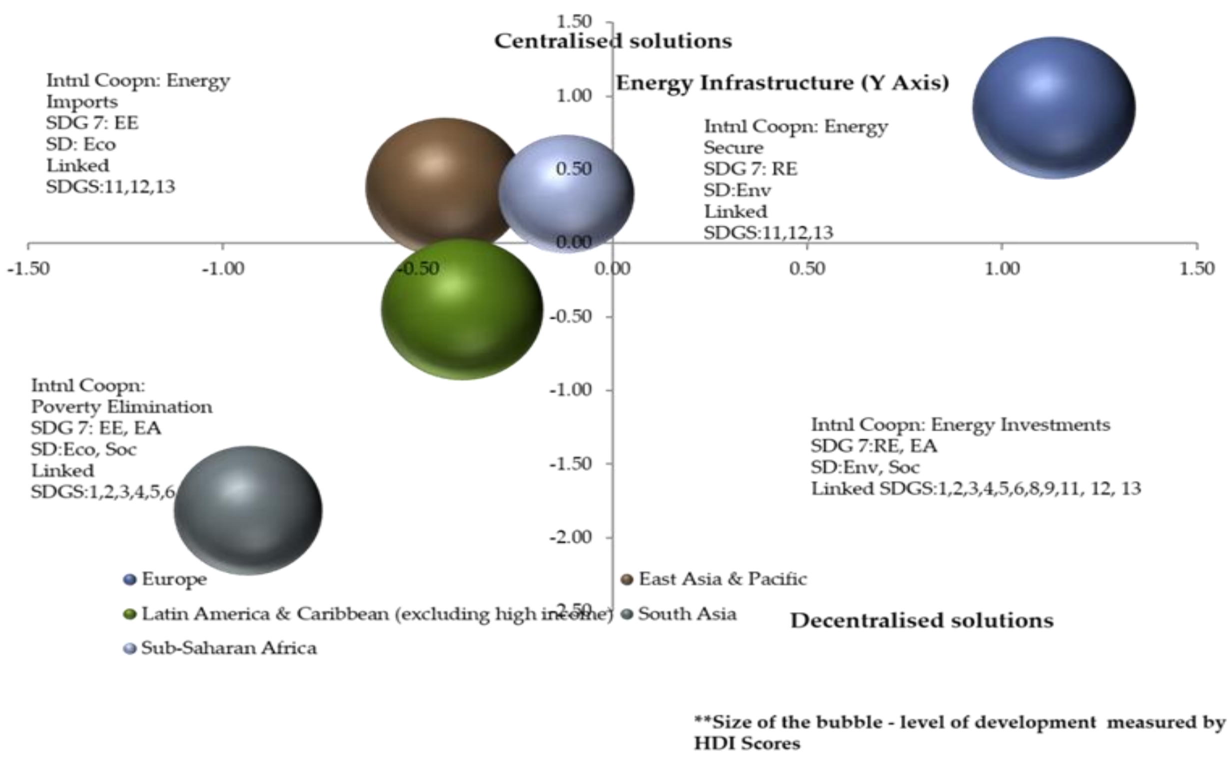

Figure 3: Regional Positions - Adapted from Srivastava, L. et al. (2018)

The above frame is an indicative attempt to highlight the policy prioritization and futuristic policy action patterns of regions and countries to balance their economic, social, and environmental goals of sustainable development and human Progress by addressing the interlinked SDGs as a means to human Progress. This does not attempt to give rise to "definitive" answers on the essence of interlinkages between SDG 7 and other SDGs to attain human Progress. This frame only acts as a starting point for policy and strategic dialogues for future regional/country-level attainment of human Progress by using energy access, efficiency, and sustainable, renewable energy for all to achieve human Progress. However, the level of such human Progress must be regularly measured for every country and region through different frameworks. The following section attempts to highlight a few such existing frameworks.

4. **Effectiveness, Practical Operationalization, and Strength of the Proposed Framework**

The proposed progress framework of energy access through its economic, social, governance, and environmental subdomains can be proposed to identify the critical sustainability and scalability elements of gendered sustainable livelihoods through elements such as renewable energy, women entrepreneurship, livelihood generation projects, among others, which has a connection with human Progress, as defined by Bond (2006). It also explicitly interlinks with various SDGs (SDGs 1,2,3, 7, 8,10, and 17). This is shown through a quadrant-specific analysis of countries from different regions at various levels of Progress, energy access, access to energy resources, and infrastructure. The proposed definition of Progress and the quadrant-specific positioning of countries opens out a new dimension of measuring energy access, Progress, and human development in an interconnected manner.

The operational structure of the measurement process of the proposed framework of measuring energy access, Progress, and development will consist of a scaling matrix for each project that connects renewable energy, women entrepreneurship, and livelihood generation for women, measured through SDG-specific indicators. The scaling matrix for each project will have inward and outward indicators. The indicators will be mapped to different SDGs. Let us illustrate the mapping and measurement of Progress at a project level through an example.

For instance, a village community has a solar home lantern project. The solar home lanterns are assembled in a community station run by women in the villages. The solar home lanterns are distributed to village households through a rental structure. The light provided through the solar home lanterns enables the household members to study, create new businesses, and run shops. To assess the critical sustainability and scalability element in this project, a set of indicators can be identified representing No Poverty (SDG1), Good Health and well-being (SDG3), Quality Education (SDG4), Gender Equality (SDG5), Affordable and Clean Energy (SDG7), Decent Work and Economic Growth (SDG8), Reduced Inequalities (SDG10), Partnership for the Goals (SDG17). As a future work, an input and output matrix, as proposed in Annexure A, could be further developed to empirically strengthen the proposed framework on energy access and progress interlinkages for the future.

For each project, once this matrix is created and constructed, a cross-comparison can be made between different projects to address how far they are critical and scalable. The numbers in the matrix will emerge from project-based qualitative and quantitative interviews or mapping done through a review of the impacts created by the projects on different SDG indicators, which are mentioned in the illustration above. The matrix will also help policymakers understand the prioritized, potential SDG-specific intervention areas to make any project critically sustainable or scalable by analyzing the outward and inward effect values received by each identified indicator encompassing the different SDGs.

5. Concluding remarks

This paper presents a unique contribution to the field of energy access framework. It introduces an interconnected energy access framework supported by a human progress-based foundation and a capability-based framework. This framework establishes connections between SDGs 1, 2, 3, 7, 8, 10, and 13. Based on this framework, the paper recommends country-specific policy prioritization for different regions, including Europe, Africa, Latin America, South East Asia, and East Asia.

Additionally, the paper proposes a project implementation framework that aligns with the energy access framework across various groups of countries. The proposed implementation framework stands out because it assists in identifying and prioritizing renewable energy and energy access projects for scalability and sustainability outcomes. The paper also attempts to underscore the importance of prioritizing, selecting, and implementing integrated policies targeting energy access and clean energy transition by emphasizing futuristic SDG-based inward and outward linkages. This approach aims to achieve tangible outcomes in the domains of SDGs 1, 2, 3, 7, 8, 10, and 13.

However, it is essential to consider robust monitoring and impact evaluation techniques in the future to assess the performance of the identified policies and projects within diverse countries and local contexts. Implementing an impact evaluation framework will strengthen countries' commitment to achieving net-zero goals through a worldwide people-centered energy transition.

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ANNEXURE A: PROPOSED PROJECT TEMPLATE OF MONITORING PROGRESS THROUGH SDG INTERLINKAGES

Outward Effect[3]------------□ Inward Effect[4]	No Poverty (SDG1) (Column 1) (Indicato	Good Health and Wellbeing (SDG3)	Quality Education (SDG4) (Column 1)	Gender Equality (SDG5) (Column1) (Indicator	Affordable and Clean Energy (SDG7) (Column	Decent Work and Economic Growth (SDG8) (Column	(Column 1) (Indicator7)	Partnership for the Goals (SDG17) (Column1)	Total Score

[3] Numbers will be given in the matrix through stakeholder consultation, a secondary literature review, and a survey based on a particular project implemented by an agency.
[4] Numbers will be given in the matrix through stakeholder consultation and a secondary literature review.

	r1)	(Column 1) (Indicator2)	(Indicator3)	44)	1) (Indicator5)	1) (Indicator6)		(Indicator8)	
No Poverty (SDG1) (Row 1) Indicator1)	1	2	3	3	2	3	3	3	20
Good Health and Wellbeing (SDG3) (Row2) (Indicator2)	2	1	2	3	2	2	4	3	19
Quality Education (SDG4) (Row 3) (Indicator3)	2	2	1	3	4	3	3	2	20
Gender Equality (SDG5) (Row4) (Indicator4)	3	2	3	1	3	2	3	2	Sum of columns
Affordable and Clean Energy (SDG7) (Row5) (Indicator5)	2	2	3	2	1	3	2	1	Sum of columns
Decent Work and Economic Growth (SDG8) (Row 6) (Indicator6)	2	2	2	1	2	1	2	1	Sum of columns

Reduced Inequalities (SDG10) (Row7) (Indicator7)	3	1	2	3	2	2	1	2	Sum of columns
Partnership for the Goals(SDG17) (Row8) (Indicator8)	2	2	2	1	1	2	2	1	Sum of columns
Total Score	17	The sum of all rows	The sum of all rows	The sum of all rows	The sum of all rows	The sum of all rows	The sum of all rows	The sum of all rows	

Note: A scale of inward and outward impact will be created from 1 (low), 3 (moderate) to 5 (high). In the above project, the total outward SDG effects of the solar home-system project are measured by the sum of columns, and the sum of rows measures the inward SDG effects of the solar home-system project. Any other project, like the distribution of improved cooking systems and the creation and distribution of such cooking systems involving women entrepreneurs, can also create a similar matrix. However, the identification potential of whether both projects are critically sustainable will be based on the following conditions – a) Inward SDF Effect (Measured by the sum of rows) = Outward SDG effect (Measured by the sum of columns), and the project will be scalable if Outward SDG Effect (Measured by the sum of columns) > Inward SDG Effect (Measured by the sum of columns). Based on the numbers emerging out of the project-specific matrix, it can also be identified which projects are both critically sustainable and scalable (Outward Effect>Inward Effect), critically sustainable but not scalable (Outward Effect =Inward Effect), neither critically sustainable nor scalable (Inward Effect >Outward Effect)