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The Relationship between Renewable Energy & Economic Development: Energy Efficiency in Developing Countries

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ABSTRACT

The efficient usage of energy is imperative for pushing an economy forward sustainably. This research studies the nature of the relationship between emission production, renewable energy, and economic development by performing a comparative analysis between developing countries. The country's renewable energy share in power generation, emission statistics, and current state of energy usage are examined. Financially and environmentally sustainable practices that can be pursued by low-income countries are further discussed.

Keywords: Green hydrogen, DRE, emissions, energy consumption.

INTRODUCTION

Developing countries struggle with the challenge of growing to the point where they are comparable to advanced economies while conserving their resources for further development. At the same time, they are faced with the need to reduce emissions and environmental degradation, a task developed countries had not prioritized while growing their economies to their current extent. This calls for the efficient use of the various forms of energy the country has the potential to generate.

Energy efficiency involves maximizing the output per unit of energy consumed, as well as maintaining a balance between the consumption of conventional and renewable sources. Conventional energy sources comprise fossil fuels (primarily coal, oil, and natural gas.) They are non-renewable, polluting, and generally considered environmentally hazardous. Renewable energy sources are self-replenishing and have a relatively lower carbon footprint. They are generally expensive and have a high cost of production per unit.

What qualifies as a developed country? A metric distinguishing developed and developing countries is its HDI (United Nations Human Developmental Index), where a country with a 0.8+ HDI is considered "highly developed". Along with this, World Bank classifies countries into high, upper-middle, lower-middle, and low-income economies.

This paper aims to investigate the relationship between renewable energy and economic development by performing a comparative analysis of energy efficiency across various developing countries. Furthermore, it identifies the economic steps that can be taken to reduce emissions at a small, subjective scale.

LITERATURE REVIEW

Research conducted in the recent past surrounding economic development and energy consumption has concluded the presence of a variable correlation between the two. Some studies suggested that upon reaching a certain level of development, the country no longer falls prey to energy overconsumption.

One such is the Hansen-Prescott model, which argues that advanced economies have "freed themselves from the constraints of energy resource limitations" (Hansen & Prescott, 2002). Shahbaz et al. (2017) added that the statement wouldn't stand if countries continue to demand energy for economic growth. Further contradicting the Hansen-Prescott Theory, they found that globalization can be positively or negatively linked with energy usage. Out of the 25 developed countries that were studied, 12 had seen an increase in consumption with globalization. The USA and the UK saw a reduction in consumption as they brought down energy usage for economic activity. They concluded that the cointegration of globalization and energy consumption isn't unidirectional (Shahbaz et al., 2017).

This finding is supported by the EKC (Environmental Kuznets Curve), which establishes the (inverted) U-shaped relationship between economic development and environmental degradation. In the initial stages of development, there is an increase in energy consumption and environmental degradation, which comes down when economies can afford to adopt renewable energy sources and "sustainable practices" (Xing et al., 2023).

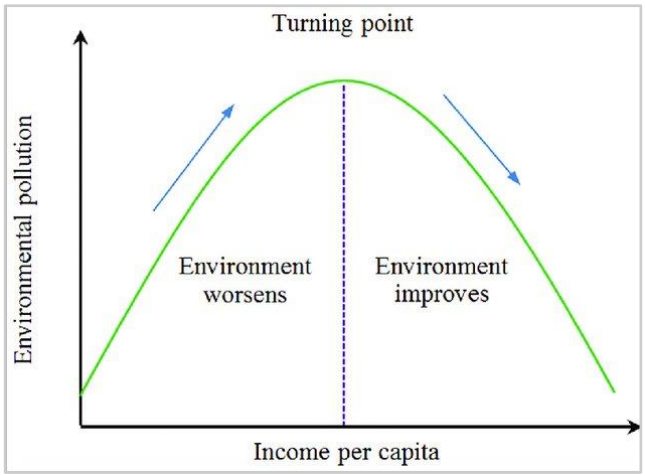

Figure 1: Environmental Kuznets Curve
Source: Phong (2019)

Low-income countries travel along the upward trajectory of this parabolic curve. Here they face the challenge of trying to achieve the same sustained economic growth developed countries have (Khan et al., 2022). To raise their per capita income or HDI to a level where they are comparable, environmental degradation is inevitable.

Griffith-Jones et al. (2012) believed a global transition to renewable energy would not be possible as low-income countries cannot be expected to "subsidize development of a renewable energy sector". They argued that it isn't likely for developing countries to sacrifice their development in favor of emission reduction. From the above-stated research standings, it can be inferred that a universal movement away from conventional forms of energy cannot be expected in the near future. The dependence of developing countries on non-renewable forms of energy is further strengthened by advanced economies themselves. Developed countries have established strict environmental laws. This has caused a shift of high-emission industries into the surrounding developing countries (Kahandagamage, 2013). This implies there is no net reduction of emissions, even if a particular country might be lessening its own carbon footprint.

Energy Efficiency Across Various Developing Countries
Different developing countries lie on different planes when it comes to energy efficiency. The countries discussed ahead were chosen due to their variation in (a) economic status; (b) energy consumption; (c) renewable energy dexterity; (d) emission production.

China:
Despite being the world's second-largest economy as of 2023, China is still regarded as a developing country. It released 11.47 billion metric tons of production-based emissions in the year 2021 (does not account for consumption-based emissions) (Friedlingstein et al., 2022). Zhao et al. (2020) found that financial development drives the consumption of renewable energy in the country, whereas trade openness drives that of non-renewable energy. As internationalization of trade also brings down renewable energy usage, it leads to an overall increase in emissions.

As a country with a high GDP, China can afford to invest in alternative energy sources. While coal still accounts for 62% of the country's energy generation, it is the largest consumer of solar energy as well as the largest producer of solar panels, holding shares in almost every stage of manufacturing. It also has high potential in the growth of biomass as a contributor to energy generation.

The biggest stride China has taken in the recent past (as of 2023) is establishing its Carbon ETS (elaborated under implication and implementations, point 2). CO2 emissions are expected to peak in 2030 and achieve carbon neutrality (no net increase in emissions) by 2060 (China National ETS, 2023).

Pakistan:
According to the UNFCC, Pakistan is responsible for less than 1% of the world's emissions. This is an impressive statistic, but indeterminate as the country falls far short in terms of energy efficiency and dexterity.

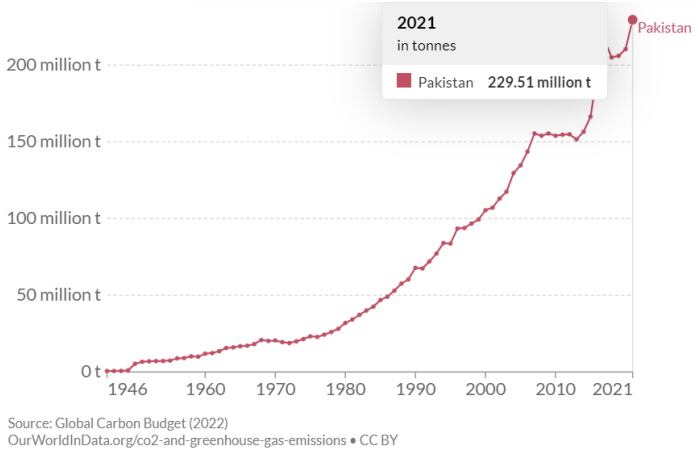

Figure 2: Annual CO2 Emissions - Pakistan
Source: Ritchie (2022)

Pakistan has been in a constant electricity crisis since 2006, with an inconsistent yet expensive power supply. Energy demand is on the rise while its generation is deficient. Jamil & Ahmad (2010) explained this deficiency in generation capacity as insufficient government efforts and policies, and further stated "utilities tend to rely heavily on electricity rationing". Another contributing factor is the lack of proper investment in the power grid. This has formed a positive feedback loop. The ongoing economic crisis leads to insufficient funding, contributing to the energy crisis, which in turn hampers economic development. This has trapped Pakistan in a cycle of energy inefficiency. Harnessing renewable forms of energy could serve to break this cycle to some extent.

Pakistan has the potential to generate a substantial amount of renewable energy, but its current share in electricity generation is barely over 5%. (Shah &Solangi, 2019). It has high geographical potential for solar energy as it sees around 3000 hours of sunshine per year. Despite the high initial cost and weather-sensitive nature of solar energy harnessing systems, they would aid the agricultural sector significantly (Mustafa et al., 2022). This is pivotal as the inconsistent power supply is a leading cause of low agricultural productivity in the country. As the agricultural sector is one of its biggest sectors, the country also churns out large quantities of agricultural refuse. This refuse has the potential of being turned into biogas and used as fuel. Shah &Solangi (2019) identified the Sindh area as a prime location for cost-efficient generation of high-yielding wind power energy. Research conducted by Ahmad et al. (2022c) emphasized the country's ability to produce geothermal energy, which if progressed could be used to generate hydrogen.

Costa Rica:
Costa Rica capped CO2 emissions at 7.82 metric tons in the year of 2021. (Ritchie, *our world in data* 2020). In 2017, 100% of the Costa Rican national grid was powered by renewable sources of energy for 300 days in a row (Richmond-Navarro et al., 2019). In 2020, 99.78% of the country's emissions for the entire year were accounted for by renewable energy.

The majority of this energy is hydroelectricity, being produced by harnessing the country's extensive network of rivers.

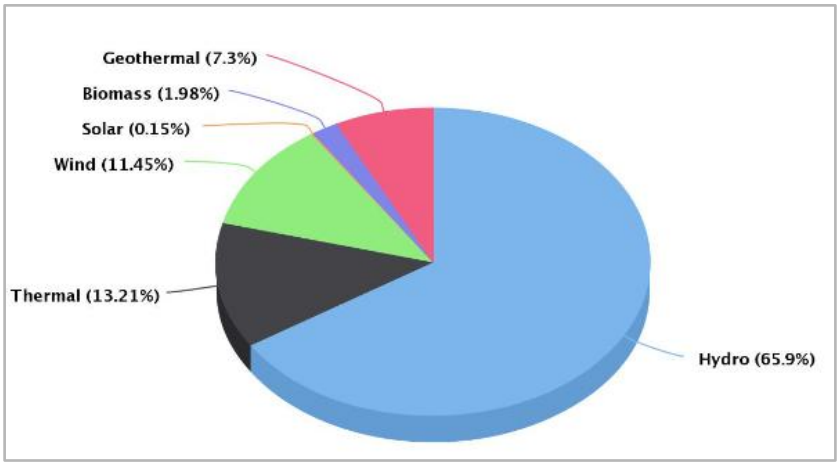

Figure 3: Renewable Energy distribution - Costa Rica
Source: BNamericas (2020)

While this has enabled the country to achieve a successful transition away from traditional fossil fuels, environmental degradation has hiked. Tropical rivers are losing water and aquatic biota due to the increasing alterations by dam construction (Anderson et al., 2006).

Implications & Implementations
Developing countries can't be expected to follow the same set of sustainable development systems as developed countries. It is unfair to ask low-income countries to bring down their emissions at the expense of economic development when developed countries like Russia and The USA have already created a large carbon footprint to evolve their economies to what they are now.

That being said, the above country analysis indicates that there are steps developing countries can take to improve energy efficiency economically.

Harnessing Green Hydrogen
Green hydrogen is one of the most sustainable forms of energy. It beats most other renewable forms of energy as it-

- is synthesized via the electrolysis of water (using an electric current to split water into hydrogen and oxygen (Oliveira et al., 2021);
- does not produce emissions when transformed from gas to power- can be converted into electricity and used without the production of CO2 (Vassilev, 2020);
- can be transported easily through pipelines due to its high mass-energy density and lightweight, as well as in the form of liquid fuel on ships (Tarkowski, 2019);
- can be stored seasonally in the form of hydrogen.

An identified drawback to this is hydrogen takes up more space than other gases. Tarkowski and Uliasz-Misiak (2022) deemed hydrogen's volumetric energy density as a disadvantage as it leads to extremely low temperatures and high pressures, reducing its storability.

Emission Trade Schemes (ETS)
World Bank defines ETS as "an explicit carbon pricing instrument that limits or caps the allowed amount of GHG emissions and lets market forces disclose the carbon price through emitters trading emissions allowances". Authorities distribute emission allowances to major emitters. (The total amount of allowances is equal to the pre-decided emissions cap). These allowances can be bought and sold on the exchange. After a decided period, the emitters must have enough allowance to account for their emissions.

This is an internalized, self-working, and self-motivating way of bringing down environmental degradation by emitter groups.

Distributed Renewable Energy (DRE) Techniques
Vezzoli et al. (2015) defined DRE generation as "Small-scale generation plants harnessing renewable energy resources at or near the point of use, where the users are the producers – whether individuals, small businesses, and/or a local community." This system of generation involves transitioning to renewable energy economically and ethically. Bacchetti et al. (2016) emphasized that DRE systems were easy to install and manage, which encouraged individuals to harness this method of production. "This characteristic fosters democratization of access to resources while enhancing local employment and dissemination of competencies" (Bacchetti et al., 2016).

Dispersed/Distributed generation (DG) technologies can catalyze the production of renewable energy at a small scale as they provide power closer to the consumption center than central station generation (Yammani et al., 2012). It should be noted that power generated by DGs is of a relatively lower voltage type.

Protection From Developed Countries
As developing countries progress their environmental conservation further, they implement new laws and policies that render their high-polluting machinery and technology useless. These are then sold to developing countries, where they continue to generate emissions. This puts these low-income countries in a vulnerable position and no real reduction in the planet's deterioration. Establishing laws and policies that protect developing countries from this form of exploitation could result in a reduced carbon footprint.

CONCLUSION

A dynamic relationship exists between renewable energy and economic development. Efficient energy usage and attempted reduction of emissions are imperative, regardless of a country's status as developed or developing. The extent of implementation and steps taken to achieve this is what is heavily dictated by their economic condition and resource availability. Large discrepancy across developing countries calls for them to analyze their own condition,

potential, and priorities independently, in order to set viable and achievable goals. Future research should focus on investigating country-specific demands to improve energy efficiency and environmental conservation.

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