Green Energy in Developing Countries

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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The global climate crisis presents a formidable challenge to humanity. NOAA has projected that by the end of the century, global temperatures could increase by at least 5 degrees Fahrenheit above the 1901-1960 average, and potentially as high as 10.2 degrees Fahrenheit (Lindsey & Dahlmann, 2023). Such drastic temperature increases would result in disastrous impacts on our planet, including rising sea levels and more frequent extreme weather events. To mitigate these effects, immediate action must be taken to reduce greenhouse gas emissions and shift towards sustainable energy sources.

The challenge of ensuring all nations have the means to participate in reducing emissions through the adoption of renewable energy technology is complex. The disconnect between the priorities of developed and developing nations is often evident, which creates a rift. At the United Nations climate talks in Copenhagen in 2009, the then Prime Minister of Lesotho, Pakalitha Mosisili, rejected the Kyoto climate proposal, stating "[Lesotho] respectfully [reminds] rich countries- you have the responsibility for delivering a good climate deal, but we, the poor countries, have the right to refuse a bad deal" (Reuters, 2009). The struggle for equitable and fair climate policy between these two worlds persists, and we must work towards strengthening relationships and bringing all nations together in the fight against climate change.

The objective of this research is to analyze how different renewable energy programs can be implemented in developing countries, and to build a set of principles based on past lessons learned from currently implemented projects. I outline recommendations for specific policy in certain countries using lessons learned from previous projects to create more effective programs that do not conflict with the host nation. I begin with a section on the challenges developing countries face with green energy, how some countries have overcome these challenges, and how

some countries face future threats from foreign investment. I then conclude with a section discussing principles that can be applied to new energy programs going forward.

I analyze previous energy programs through the lens of Social Construction of Technology (SCOT), defined by Trevor Pinch & Wiebe Bijker (1984) as an analysis of relevant social groups that use and are influenced by a piece of technology. SCOT looks closely at the relationships between the technology and these groups, while also viewing how these groups affect each other. SCOT also recognizes interpretive flexibility, or how a certain piece of technology can sustain divergent opinions about its use across different people. This comes into play when considering regional needs of a population, and green energy use will vary country to country.

I will also look at these programs through the lens of diffusion of innovation analysis, developed by Everett Rogers (1983). Diffusion of innovation identifies the different stages of adoption for a specific technology and analyzes how technology can become widespread as more and more people begin to understand and use it. This framework recognizes different groups that arise when a technology is being adopted by society. These groups include innovators, early adopters, the early and late majority, and laggards. With respect to the adoption of green energy in developing countries, the focus will be on the early adopters of the technology, because the objective of analyzing these energy systems is to understand how to diffuse the technology more quickly, not to create new technology as innovators do.

Using these frameworks, I attempt to identify the best and worst qualities of previous green energy programs in these countries, so that new policy can be recommended and implemented to reduce current emissions while creating a foundation for further decarbonization in the future. It is critical that energy sources be shifted towards less emissions now, as more and

more irreversible damage to the environment is done each day that no action is taken. Not only do we need to come together to help these countries get reliable, renewable power, we need to ensure that there is no chance of a relapse into dirtier forms of energy production if there are setbacks in the process. We must balance practicality with idealism and create policies to last for a sustainable future.

CURRENT STATE OF ENERGY IN DEVELOPING NATIONS

Before analyzing current energy programs, it is important to correct a few commonly held beliefs about third-world emissions. Many people believe that developing countries are the largest carbon dioxide emitters globally due to the widespread use of fossil fuels in these countries. However, Bolin & Kheshgi's (2001) analysis of emissions between "Annex 1" countries (developed countries including those in economic transition) and "non-Annex 1" countries (i.e., developing countries) demonstrated the inequalities between each while generating projections for the future. The authors aimed to dispel myths about developing nations' CO2 emissions and found that the United States emits 5.2 tons of carbon per capita each year, while the average non-Annex 1 country emits 0.57 tons of carbon per capita each year (Bolin & Kheshgi, 2001). In simpler terms, each American citizen in 2001 emitted 10 times as much carbon dioxide as most of the world population, and Annex 1 countries emitted an average of 5.5 times more than non-Annex 1 countries.

While it may seem unnecessary to implement green energy policy in developing countries due to their lower carbon dioxide emissions, it is crucial to shift towards sustainable energy sources in these regions to address the long-term future of climate change. Bolin &

Kheshgi's (2001) projections demonstrated that from 2001 to 2010, the population of non-annex 1 countries was predicted to increase by 5.6 billion, quadruple the projected population in annex 1 countries. This population growth continues today, with UN projections estimating that the population of developing countries could surpass 9 billion by 2050 (Haub, 2008). As energy use will grow exponentially with this rapid population growth, energy sources must shift from fossil to renewable sources to decrease future emissions. It is critical to lay the groundwork for renewable energy systems as soon as possible to ensure that green energy becomes a fundamental part of a nation's development, enabling the use of these innovations in the future as they continue to grow.

The Cost of Energy

The cost of implementing green energy remains one of the most significant obstacles in developing countries. The limited resources of these countries and competing priorities make it challenging to allocate significant funds to more expensive renewable energy systems like solar, wind, and hydroelectric power. For example, constructing an average solar farm costs $2,921 per kW, while an average natural gas-fired power plant only costs $812 per kW in construction costs- less than a third of the amount (Gerardi, 2021). This is primarily due to the high cost of implementing advanced technologies in green energy systems, which are in high demand globally, driving up prices and making it challenging for developing countries to transition to renewable energy sources.

Microgeneration

Microgeneration can provide an affordable and sustainable solution to these problems and is particularly useful in rural areas where grid access is limited. By generating energy at a small

scale, local communities can become energy independent and avoid the high costs of larger-scale energy systems. This approach also has the added benefit of reducing transmission and distribution losses associated with larger systems, which can be as high as 15% or more in some cases (CHINT, 2021).

Additionally, microgeneration can be powered by a variety of renewable sources, including solar, wind, and hydropower. These sources of energy are often abundant in developing countries, providing an opportunity for local communities to harness their natural resources and reduce their dependence on fossil fuels. Microgeneration systems can also be integrated with energy storage technologies, such as batteries or pumped hydro, to ensure a consistent supply of energy even during periods of low renewable generation.

Governments and international organizations can play a crucial role in supporting microgeneration initiatives by providing funding, technical assistance, and policy support. These efforts can help to overcome the initial costs of setting up microgeneration systems and build the necessary infrastructure to support them. In addition, governments can provide incentives for households and businesses to adopt microgeneration technologies, such as tax credits or feed-in tariffs. By prioritizing microgeneration, developing countries can take a major step towards achieving sustainable and equitable energy access for all.

African countries often benefit the most from microgeneration programs, as many African countries do not have a widespread central grid infrastructure already in place, and microgeneration systems do not have to be connected to a grid to serve the needs of the community. Puliti (2022) states that “West Africa has one of the lowest rates of electricity access in the world; only about 42% of the total population, and 8% of rural residents, have access to electricity” (para. 2). To the staggering 92% of people in rural West Africa without electricity

access, microgeneration programs can be life changing, while providing great environmental and health benefits to the local population.

A prime example of a successful microgeneration program is in Robben Island, a South African island in close proximity to Cape Town, and registered as a UNESCO World Heritage Site due to it housing high-profile prisoners such as Nelson Mandela since the end of the 17th century (Robben Island Museum, n.d.). Because the island was designed to be completely isolated from the mainland, the island relied on local diesel generators to produce electricity, instead of being connected to the South African grid. The environmental consulting firm WSP was appointed by the National Department of Tourism of South Africa to create a microgeneration system for the island, and the resultant energy system is still in place today.

Using a combination of solar and battery power, WSP installed an extensive solar farm and integrated energy storage system that saves 280,000 liters of diesel fuel per year (WSP, 2017). This system works in harmony with the local environment and does not disturb historical sites or endangered species present on the island. Moreover, the system repays for its own capital costs within five years, making this microgeneration system a logical choice economically for the local government. WSP's careful consideration of heritage sites and wildlife is something that should be present in any green energy system, and green energy policy moving forward should look to Robben Island as an example. This system shows how consideration of the local environment combined with innovative technologies allow more effective systems to be put in place.

Untapped Potential

Several developing countries currently have vast potential to produce most of their power from renewable sources, but economic roadblocks have prevented this from happening. Morocco is one of these countries and could be powered by either solar or green hydrogen energy if resources were available to commit to the project. Currently, Morocco imports 91% of its energy through fossil fuels, with almost 70% of these imports being coal as Morocco generates 46.7% of its power from coal-fired plants (Touili et al., 2018). While Morocco has limited local energy resources like natural gas or oil, it has one of the best environments to implement green energy technology for large-scale power generation. The estimated wind energy potential across Morocco's vast coastline is 25,000 MW (Touili et al., 2018), enough to power about 2.35 million average American households per year (U.S. Energy Information Administration (EIA), n.d.).

While the Moroccan government has made steps to reduce reliance on imported power, much of this energy potential remains untapped. SCOT analysis of the social groups involved in Moroccan power generation reveals that implementation of wind and solar programs is in Morocco's best interest. The relevant social groups in this scenario are the Moroccan government, its people, and the foreign nations selling fossil fuels to the country. When fuel is imported, the selling country has a profit motive to mark up the price of these goods, and increase the average cost of energy. This directly affects the Moroccan people's cost of living and weakens the Moroccan government's ability to negotiate and pursue its interests on the global stage. The nations that Morocco buys fossil fuels from gain a significant advantage when negotiating policy and can leverage Morocco's need for their fuel to tip trade deals in their favor. If Morocco gains energy independence by tapping into their wind and solar potential, they gain an edge in geopolitical negotiation while directly improving the lives of citizens. The decrease in

pollution and heavy industry will greatly benefit the nation, as much of Morocco's economy is reliant on tourism of its natural environment and historical sites (Touili et al., 2018). The lack of pollution from fossil fuel power generation will make preserving the natural environment an easier task, and the funds saved from reduced cost of environmental cleanup can be redirected to where the country needs it most.

Morocco's use of green energy can also be used as an example of interpretive flexibility. For Morocco, wind power across their coastline would significantly improve their economy and help them to gain an advantage in the geopolitical space. Morocco could see this technology as an essential part of their critical infrastructure, and a large focus would be placed on this technology if implemented. In comparison, the system on Robben Island as discussed earlier uses green technology for other purposes. For South Africa, Robben Island's system is not viewed as a piece of critical infrastructure for the nation at large, rather it is a demonstration of the technology in use as a proof of concept. Additionally, South Africa may have been more motivated to create the system due to the intense logistics required to supply Robben Island, with the endangered species on the island coming into play as well. This demonstrates how green energy technology can have a completely different meaning to different groups based on a variety of external and internal factors, and is an example of interpretive flexibility through SCOT.

The Effects & Dangers of Foreign Investment

Developing countries often do not have the resources to handle the massive costs required to build significant green energy infrastructure, so they often rely on foreign investment from developed nations to ease the financial burden. However, relying on foreign investment can

lead to many problems, including cultural conflict, pseudo-colonization, and lack of independence.

Fig. 1 outlines a visual representation of SCOT theory and is adapted to show all the relevant groups involved in renewable energy programs and the relationships between them.

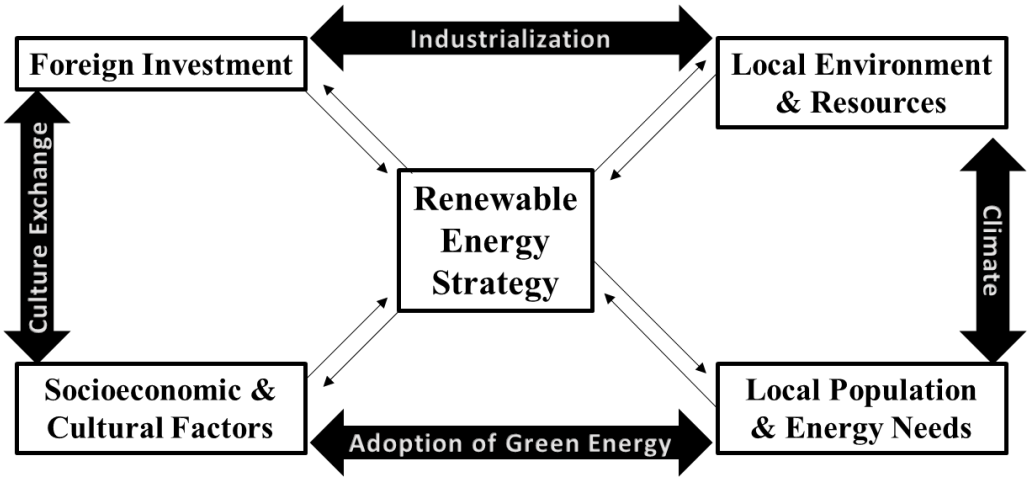

Figure 1: Social Construction of Technology (SCOT) Model for Renewable Energy Strategy in Developing Countries. The figure identifies major social groups that are interrelated to the strategy, and outlines how these groups can affect each other.

The figure demonstrates that foreign investment can impact the local environment and deplete resources, but it also is influenced by cultural and socioeconomic factors of the recipient country. It is important to note that foreign investment can lead to different types of industrialization based on what resources are available. For example, if the developing country receiving aid has large reserves of rare earth materials, investment may focus on heavy mining operations that cause significant environmental damage since the operation would be very profitable. The key to reducing environmental impact and managing emissions with foreign investment is to industrialize responsibly, and to ensure that the new energy demand from industry can be met by clean forms of generation.

One of the biggest threats to the long-term future of foreign direct investment (FDI) to developing nations is the increase in natural disasters and extreme weather events that is occurring due to climate change. According to (Chen et al., 2022), “The direct damage caused by climate change, such as destruction of production materials, decline in output, staff shortages and reputation loss, can eventually result in a fall of foreign capital inflows” (p. 1725). Foreign direct investment is often performed by for-profit corporations, investment banks, or governments that have an incentive to create investments with growth potential. Green energy projects require high capital costs to construct, and the threat of natural disasters destroying the new infrastructure may cause investors to back out upon executing a cost-benefit analysis. The effect of extreme weather also compounds onto the construction costs because further weatherproof systems and safety precautions are required. The result of this phenomenon is that the countries that need green energy the most are neglected when foreign investors are looking to create energy programs.

Another major factor in foreign investment is the role of governance in the developing country. Chen *et al.* (2022) states that “Countries with good governance and a complete defense system tend to be more capable of dealing with climate disasters and building up stronger resilience to the detrimental effects of natural disasters. Conversely, poorly planned development, lack of a proper regulatory system, and weak governance aggravates the vulnerability of many small island developing states to disaster risks” (p. 1726). A snowball effect can once again be observed with respect to a developing country’s local government, similar to its vulnerability to natural disasters and extreme weather. If a local government is in turmoil, and law & order is not well established in that country, foreign investors are much less likely to see that country as a good investment for green energy technology. Once again, these

countries are often in the most need for clean power, as their people can suffer from the lack of governance in that society.

Lack of governance can also lead to a vulnerability for world powers to use their resources to slowly take over a developing nation's critical infrastructure in order to gain influence in that country. Research performed by The Borgen Project, a nonprofit organization dedicated to reducing poverty and world hunger, conducted research in regards to China's foreign investment in African critical infrastructure. The findings state, "countries in Africa need to remain alert to the potential risks of the tempting FDI pouring in from China. There are risks of African countries falling into unobtainable levels of debt. . .[for example,] the Mombasa-Nairobi rail went four times above the planned budget for Kenya, with China financing 80%" (Cochrane, 2022). While Kenya specifically does not necessarily have poor governance, China has in recent years greatly increased their foreign investment in Africa, rising from $74.8 million in 2003 to $5.4 billion in 2018. Countries like Kenya must be cautious to allow such a large foreign power to have direct control over the design and implementation of critical infrastructure, which includes energy projects as well as rail & transport infrastructure. If countries cannot pay back their debts to the foreign power, the investors are able to take direct control over that infrastructure, dealing a massive blow to the independence of the developing nation in question.

This can lead to a scenario of Neo-Colonialism, whereby developing countries are forced into situations where they voluntarily give up their own control of critical infrastructure to foreign powers, allowing for the foreign power to heavily influence the region. Neo-Colonialism is when a state appears to have control over its economy and politics, but "in reality its economic system and thus its political policy is directed from the outside" (Nkrumah, 1976, p.ix). This is in contrast to traditional colonization, usually done through force and threat of violence. This type

of control over a country can be more malicious than traditional colonization, since the citizens might not be aware of the risks of foreign investment or could be convinced that the benefits of improved energy & transportation systems outweigh the risks of being under the control of a foreign power. In an ideal world, each country should be able to generate their own power and operate using local resources without outside investment. However, globalization of the economy and the economic disparities between countries makes this virtually impossible in some countries, leading to a need for responsible foreign investment. International regulation should be implemented to mitigate the negative effects of foreign investment by preventing projects that could put a developing nation in massive debt, so that developed nations can simultaneously profit from investments without negatively affecting the population of that country.

Despite its drawbacks, foreign investment still has a significant positive impact on green energy and often results in reduction of carbon emissions from developing countries. While China has been accused of some malicious investment tactics, the Chinese program of Official of Developmental Assistance (ODA) has helped many countries in sub-Saharan Africa to implement green energy programs and reduce their emissions. The funds allocated to the ODA program are used “to help SSA countries get rid of poverty and realize social development and social structural adjustment”, and “to help them develop cleaner renewable energy sources and reduce carbon emissions” (Wang et al., 2021). If these goals can be realized, the outlook for developing nations in the region is very positive. The ODA program was created to help achieve the UN Sustainable Development goals, and if the funds can truly be used for this purpose, then these countries will have a stable platform upon which to continue development into the first world.

Research on the effect of ODA on these countries has found that the impact of the investment is dependent largely on local socioeconomic factors. One effect of ODA investment is that "the impact of ODA on the renewable energy is non-linear. When carbon dioxide intensity reaches a certain value, the economy and society rely more on fossil energy consumption, so the economic cost of developing renewable energy is greater. The aid funds that should flow to the renewable energy industry have to flow to the traditional fossil energy industry, which has a crowding-out effect on the renewable energy development" (Wang et al., 2021). Across renewable energy policies, we continue to see a snowball effect, where if a developing nation is heavily reliant on fossil fuels, it becomes increasingly difficult to transition to green energy. This highlights the importance of implementation of green energy in areas without significant infrastructure currently in place, so that green energy implementation does not have to face these challenges.

Using Diffusion of Innovations theory, foreign investors can identify groups that have an interest in green technology to accelerate its growth and adoption by society. In developing countries, early adopters may include small businesses or local governments that have a strong interest in environmental sustainability, while the early majority may consist of larger corporations or government agencies that are looking to improve their public image or reduce costs. For example, only 18% of the population in sub-Saharan Africa has access to cleaner cooking fuels such as natural gas or propane (*World Bank Open Data*, n.d.). If electric cooking technology was implemented in an area supplied with microgeneration green power, home cooks and chefs could be a significant early adopter of the technology. This would generate momentum for the technology as word spreads and more people implement new cooking technology into their daily lives. Strategies such as education and awareness campaigns, financing and

investment incentives, and regulatory policies that encourage the adoption of green energy systems can also be implemented to improve adoption of the technology by the broader population. Additionally, partnerships between foreign investors and local communities or governments can help to ensure that projects are tailored to the specific needs of the community and are implemented in a way that maximizes their effectiveness and sustainability.

FUTURE PROGRAMS- PRINCIPLES FOR IMPLEMENTATION

Many lessons can be gleaned from analysis of current programs and trends outlined above. In order to ensure the sovereignty and dignity of the developing nations, a set of guidelines can be created to overcome current obstacles faced by green energy programs while also avoiding repeated mistakes from the past.

One of the key themes seen in green energy programs that must be addressed is the snowball effect discussed in previous sections. Countries that have unstable governance, extreme weather vulnerabilities, and significant existing fossil fuel energy infrastructure face greater challenges to full implementation of green energy programs. Government instability leads to a lack of resources to commit to green energy while also reducing foreign energy investment due to increased risk. Extreme weather and natural disasters have a similar effect, whereby foreign investors are less likely to build energy infrastructure that could be damaged by these phenomena. Existing fossil fuel energy infrastructure decreases the diffusion of green energy programs, since building on top of existing infrastructure is inherently easier than creating new projects. Considering these concerns, the following general guidelines should be used when creating energy policy and programs to mitigate the snowball effect:

1) Foreign investment must not place the recipient country in financial jeopardy.
2) Investment should be directly placed into capital costs of green energy projects.
3) The program must consider the region's climate and choose the best possible energy source available.

These general guidelines can be applied to green energy programs to avoid the snowball effect, ensuring that the country the system is being designed for maintains its sovereignty and receives the aid it requires without being neglected due to socioeconomic and environmental factors.

GREEN DEVELOPMENT: A FUTURE FOR ALL

Through analysis of different energy programs and previous policy in developing countries, we can use the lessons learned from the past to ensure that no country, developed or developing, is left behind in the global transition to cleaner energy. Using foreign investment, profit motives can be leveraged to directly improve the lives of millions, and give them access to energy that will spur further societal advances. Green energy programs can be designed specifically for the nation receiving them, while considering the local climate, environment, and culture. Using the underlying principles of previous projects that have worked, new programs can be developed that will lay the foundation for generations of clean power to come. Ultimately all nations must join together in the common goal to stop climate change, and the developing world will be the battleground upon which the future of our planet is decided.

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