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Questioning Aid for Building Renewable Energy Capacity in Developing Countries

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Abstract

This study investigates whether capacity-building drives the association between renewable energy aid and renewable energy consumption in low-income countries. It hypothesises that renewable energy aid is positively associated with renewable energy consumption (H1) and that this association is driven by capacity-building (H2). While previous literature acknowledges that aid may promote renewable energy outcomes, the mechanism of capacity-building is often assumed rather than empirically tested. Moreover, existing research predominantly focuses on governance capacity or climate adaptation capacity within broader samples of developing countries, rarely isolating capacity for renewable energy aid or considering only low-income countries. This study addresses these gaps by disaggregating renewable energy aid into capacity-building and non-capacity-building components and focusing exclusively on low-income countries, where both the need for aid and the vulnerability to climate change are greatest.

Conducting a large-N panel regression analysis, this study examines 21 low-income countries over the 2010–2020 period. Renewable energy aid (RAID) and its capacity-building component (CB RAID) are identified through word-based filtering of project-level data from the OECD Creditor Reporting System. The dependent variable, renewable energy consumption, is expressed as a percentage of total final energy consumption. Control variables include GDP per capita, foreign direct investment (FDI), and access to electricity. All models apply fixed effects for country and year to control for time-invariant country-specific characteristics.

Contrary to expectations, results show no significant association between RAID and renewable energy consumption, rejecting the first hypothesis. Furthermore, CB RAID is found to have a statistically significant negative relationship with renewable energy consumption, contradicting the second hypothesis. Non-capacity-building RAID shows no meaningful effect. Across all models, FDI consistently exerts a strong and significant negative influence, while GDP per capita and access to electricity show no significant associations. Robustness checks using alternative model specifications confirm these results.

These findings suggest that the effectiveness of RAID, particularly its capacity-building component, is highly contingent on national contexts. The dominant explanatory power of country fixed effects further highlights the importance of unobserved structural factors in shaping renewable energy outcomes. This study's findings contribute to the academic literature by empirically isolating capacity-building within renewable energy aid and analysing its effects in a sample of low-income countries. The results call for greater consideration of recipient contexts and donor strategies in designing effective renewable energy aid.

Keywords: Renewable energy aid; capacity-building; low-income countries; renewable energy consumption; energy transition; aid effectiveness; climate mitigation.

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1. Introduction

1.1 The Energy Transition and Low-Income Countries

Energy is deeply tied to social and economic dimensions of human development (Matheson & Giroux, 2010). Besides being essential to meeting basic human needs, it is also crucial for nations' growth, contributing more than 80% to global economic development (Naheed et al., 2024). The importance of energy is consistently growing due to rapidly rising consumption and demand, led by emerging and developing economies (IEA, 2024). This demand is mainly met by non-renewable sources, as evidenced by the fact that more than 80% of total energy consumed from 2010 to 2021 was derived from fossil fuels (Naheed et al., 2024).

However, this heavy reliance on fossil fuels is leading to environmental degradation and climate change. A changing climate affects human well-being (Khan et al., 2024) by causing climate disasters and scarcity of food and water (Bhargawa & Bhargava, 2023). These, in turn, increase poverty and hunger, which affect areas of life such as health and education (Liu et al., 2024-b). These harms disproportionately affect developing and low-income countries. In 2023, the 74 lowest income countries emitted only one-tenth of global greenhouse gases (Bhargawa & Bhargava, 2023). Despite their low contribution to climate change, low-income countries are likely to bear the greatest burden in terms of loss of life and effects on economy and investments.

Within this context, dialogues on global climate policy increasingly consider the importance of climate mitigation, especially through a sustainable energy transition to renewable sources (Kim & Lee, 2021; Long et al., 2024). One example is the United Nations' 7th Sustainable Development Goal, calling for "affordable, reliable, sustainable and modern energy for all" (United Nations, n.d.). An energy transition to renewable sources could not only minimize negative environmental impacts but also foster economic growth and employment opportunities (Mehta et al., 2023). Additionally, transitioning to renewable energy could improve developing and low-income countries' energy security by reducing their dependence on imported fossil fuels (Kim & Lee, 2021). Due to these advantages, many countries have expressed their willingness to expand their renewable energy generation and consumption.

However, low-income developing countries face significant barriers to a successful energy transition. The main challenge is that overhauling existing energy systems requires substantial financial investment in infrastructure which low-income countries cannot afford (Kim & Lee, 2021). In addition to finance, low-income countries often lack technical and human resources such as technology or capacity necessary to adequately implement financial investments (Chen & He, 2013). Thus, they require external financial and technical assistance to achieve a transition to renewable energy (IEA, 2024; Kim & Lee, 2021).

1.2 Research Purpose

The above sections highlight the importance of a global transition to renewable energy sources, especially for low-income countries most affected by climate change. However, low-income countries lack the financial and technical capacity to undergo this transition, meaning they lack renewable energy capacity. Thus, they require external assistance to build this capacity, specifically renewable energy aid. A literature review in later sections will highlight that there is a lack of research on how renewable energy aid can improve renewable energy adoption through capacity-building. Addressing this gap, this study aims to investigate the following research question.

RQ: *To what extent does capacity-building drive the association between renewable energy aid and renewable energy consumption in low-income countries?*

Answering this research question contributes to academic literature by empirically testing capacity-building in relation to aid, a process which is commonly conceptualised and theorised, yet never measured. Additionally, capacity-building within the renewable energy sector is under-researched. Another academic contribution is this study's analysis of aid and capacity-building within low-income countries, which are only rarely isolated in aid literature despite often being most dependent on external support and most vulnerable to climate change.

This study is also of societal relevance. Energy is crucial for economic growth and social development (Naheed et al., 2024); thus, understanding how energy is affected by energy aid and capacity-building efforts can lead to recommendations for more effective energy aid, especially within low-income countries. The resulting improved aid can, in turn, accelerate the energy transition, especially benefiting developing and low-income countries as they currently suffer the most from climate change (Bhargawa & Bhargava, 2023).

To answer the research question, this study will conduct a quantitative large-N panel regression analysis, using data from 21 low-income countries over the 2010–2020 period. Aid is coded using a theory-based keyword approach to differentiate between projects that involve capacity-building and those that do not. The dependent variable, renewable energy consumption, is operationalized as the share of renewables in total final energy consumption. Control variables include GDP per capita, foreign direct investment (FDI), and access to electricity. The regression includes fixed effects to control for time-invariant country-specific characteristics.

The following sections will begin with a theoretical framework outlining theory from existing literature to form hypotheses and a conceptual model. Next, a methodology will present the research methods and data used. This will be followed by the results of a large-N panel regression analysis. The implications of the results will then be discussed, before concluding with research and policy recommendations.

2. Theoretical Framework

The section will open with a literature review outlining existing research on the topic of aid and climate change mitigation indicators. This will highlight research gaps which this study aims to fill. A conceptualisation will then define this study's variables, leading to a hypothesis and conceptual model which will direct the research process.

2.1 Literature Review

2.1.1 Aid and Climate Mitigation Indicators

Several scholarly works have analysed the effect of foreign aid on indicators related to climate mitigation. For example, in a study investigating 49 Asian countries from 2001 to 2019, Farooq (2021) tested the association between aid and carbon dioxide (CO_2) emissions of recipient countries. This revealed that aid may mitigate CO_2 emissions by promoting the development of sustainable technologies and expanding environmental protection activities. However, aid was also found to weaken governance conditions of recipient countries, eventually leading to reduced effectiveness of environmental protection activities and ultimately lower CO_2 mitigation effectiveness. Thus, the mitigating effect of aid on CO_2 emissions decreased over time.

Also examining aid and CO_2 emissions, Sharma et al. (2018) conducted a case study on Nepal's data from 1971 to 2013. They found higher levels of aid to decrease CO_2 emissions in the long run. Though this contradicts Farooq's (2021) findings that aid's mitigating effect may decrease with time, comparisons between the two studies should be limited due to their different samples of 49 countries and one case study. Sharma et al. explained their results by describing that aid fosters the spread of technical skills in low-carbon technologies such as solar and hydro power. This highlights the capacity-building effect of aid, a recurring theme in the literature.

Villanthenkodath et al. (2022) examined how aid impacted both renewable and non-renewable electricity generation in Brazil, India, China, and South Africa from 1995 to 2015.

Aid significantly promoted renewable electricity generation while reducing non-renewable electricity generation. Importantly, the authors also tested the effect of aid targeting clean energy sources like solar and wind, uncovering the same effects as with overall aid. It is assumed that both types of aid contribute towards the development of renewable energy technologies, expertise, and infrastructures, relating to Sharma et al.'s (2018) acknowledgement of aid's capacity-building effect.

2.1.2 Energy Aid

Villanthenkodath et al.'s (2022) choice of distinguishing between overall aid and energy-related aid is not uncommon, with some authors focusing solely on energy aid. Khan et al. (2024) examined its influence on indicators of the 7th Sustainable Development Goal of the UN. Using data on 39 countries from 2002 to 2021, they found that energy aid improved accessibility to electric services and renewable energy consumption. However, it did not enhance renewable energy generation capacity, having only a partial effect on renewable energy.

Ikegami and Wang (2021) investigated 64 countries from 1995 to 2014 and found energy aid to be effective in reducing recipients' CO2 emissions. The intensity of this effect varied across countries, as those rich in fossil fuels saw less CO2 emission reduction than those poor in fossil fuels. Similarly, for a sample of 65 nations between 2002 and 2020, Liu et al. (2023-b) uncovered a negative correlation between the same variables. They attributed this to a mechanism of energy aid as capacity-building, supporting findings related to overall aid effects. Energy aid has the potential to stimulate the adoption of low-carbon energy by reducing costs related to renewable energy production and improving recipients' capacity for developing renewable energy technology.

In a separate study on 117 countries from 2002 to 2020, Liu et al. (2023-a) found energy aid to have a positive impact on renewable energy consumption. Naheed et al.'s (2024) study on the same variables in 22 countries from 2003 to 2022 also revealed a positive correlation, finding that energy aid increased investment in zero-carbon emission sources like wind and solar. However, they also emphasized how energy aid may negatively influence the energy transition under certain conditions. If aid-recipient countries are excessively reliant on energy aid, their private sector is likely to experience modest investment in renewable energies. Other conditions include underdeveloped financial sectors which cannot fund renewable energy initiatives, weak governance and institutions which mismanage energy aid, and insufficient labour and technical expertise to implement energy aid. These conditions relate to Liu et al.'s

(2023-b) finding that energy aid interacts with countries' capacity and knowledge for energy decarbonisation.

2.1.3 Renewable Energy Aid

Several authors narrowed the independent variable and researched the effects of renewable energy aid (RAID). Kim (2018) used data from 2002 to 2015 on 88 countries to study the effect of RAID on renewable energy production capacity. They uncovered a positive relationship, attributed to aid's capacity-building effect and further supporting the common finding. Moreover, the relationship was stronger for low-income countries than it was for lower-middle-income countries, as low-income countries tend to lack more renewable energy capacity and technology compared to lower-middle-income countries. For the same variables, over 105 countries from 2000 to 2013, Haque and Rashid (2021) not only found a positive relationship; they also discovered this relationship to be positively related to the number of aid projects in the country. This suggests a cumulative learning effect, whereby knowledge and experience gained from implemented projects enhance renewable energy capacity over time.

Selecting electricity generation as a dependent variable, Yang and Park (2020) studied 98 countries from 2000 to 2014 and found RAID that the relationship was conditioned by countries' capacity to absorb and use resources, again highlighting the importance of capacity development for energy aid to affect energy decarbonisation factors. They also found the impact of RAID on electricity generation to be more significant in countries with democratic regimes or renewable energy financial incentive policies. This suggests that RAID is contingent on national contexts such as capacity and knowledge, political regimes, and policy environment.

Some studies compared RAID and non-renewable energy aid (NAID). Looking at 19 countries between 2000 and 2014, Chapel (2021) assessed the effect of RAID and NAID on electrification. Whereas RAID significantly improved electrification, NAID showed little to no impact, highlighting the importance of disaggregating energy aid into renewable and non-renewable emphases. Naheed et al. (2024) also considered RAID and NAID separately. RAID had a significantly positive influence, while NAID showed adverse effects, similar to Chapel's (2021) results. They explained that NAID affects electrification and renewable energy consumption negatively because it contributes to environmental degradation by supporting carbon-intensive measures. RAID, on the other hand, promotes renewable energy adoption by facilitating infrastructural modernisation and transformation for renewables.

Liu et al. (2023-b), who identified a negative correlation between aggregated energy aid and CO2 emissions, found that this negative correlation mainly stems from RAID rather than from NAID. Liu et al. (2023-a) also examined RAID and NAID separately and found only RAID to have a positive impact on renewable energy consumption. Lastly, Khan et al. (2024), who determined a positive effect of energy aid on energy decarbonisation, found that RAID significantly contributed to renewable energy access and consumption through the mechanisms outlined by other authors. However, it did not improve renewable energy production capacity, even worsening it in the long run. The mechanisms behind this negative effect are not detailed.

2.1.4 Capacity-Building

A review of the literature on aid and indicators of climate mitigation highlights the role of capacity-building as a mechanism driving the associations. Several studies suggest that aid, especially when targeting energy and renewable energy, can promote the development of technical and institutional capacity for low-carbon technologies. It can enhance expertise by transferring knowledge or by facilitating research and training in recipient countries. Aid may also reduce infrastructural investment costs or improve policy quality surrounding low-carbon technologies.

The importance of capacity-building is well-established in aid literature. Experience has emphasised that aid is likely to have no lasting effect if its provision is not coupled with capacity-building efforts (Godfrey et al., 2002). In 1995, Edward Jaycox, World Bank Africa Region Vice-President, stated that "whether or not you are building capacity at the national level is the only way that you can ultimately judge whether what you are doing in the area of technical assistance makes sense" (OECD, 1995, p.23). This is because developing countries often lack financial and technical resources, as well as institutions and incentive structures needed to make effective use of resources (Chen & He, 2013). Therefore, building capacity has been a common goal of international aid since the 1950s, with many projects including some elements of capacity-building (An et al., 2017). This is especially the case for environmental aid in developing countries, where adequate capacity is frequently a critical missing factor in efforts to meet sustainable development goals (OECD, 2006).

However, the effectiveness of capacity-building is contested. An overview of international aid during the 1990s from bilateral and multilateral donors found only little success in building recipient countries' overall governance capacity (Degnbol-Martinussen, 2002). Most countries remained incapable of effectively implementing development policies or maintained policies which were not conducive to development objectives. This aligns with the findings of the OECD (2006), which drew on experience from academics, bilateral and multilateral donors during the 1990s and 2000s. They found that while some countries showed improved capacity and technical cooperation with donors, most countries faced limited improvements regardless of aid amount.

On the other hand, capacity-building effectiveness has been more varied regarding climate change. Barnett (2008) conducted a case study investigating the effect of decades of aid flows on Niue's climate change adaptive capacity. They found that aid improved Niue's ability to pay for climate adaptation costs. Nonetheless, it also caused competitive aid-seeking behaviour and accountability disputes, undermining governmental legitimacy and capacity to steer climate adaptation. Thus, aid can have mixed results on overall climate adaptation capacity.

In contrast, Chen and He (2013) identified numerous successful climate adaptation capacity-building projects using data from bilateral and multilateral aid granted from the 2000s until 2013. They determined multiple conditions which led to successful capacity-building: country- and demand-driven programmes; improving recipients' education on climate change; monitoring and evaluation of results for improving effectiveness of future interventions; sharing of information and financial resources to promote best practices; and improving policymakers' decision-making processes regarding climate change. These findings provide a framework for how to maximise capacity-building through aid.

2.2 Research Gaps

The literature review highlights several research gaps. First, while some authors have identified capacity-building as a potential mechanism through which aid influences climate mitigation, it remains assumed and thus empirically under-researched (Naheed et al., 2024). Existing studies have primarily tested the relationship between aid and climate mitigation indicators, never isolating capacity-building as a separate factor. To address this, this study will isolate capacity-building by disaggregating aid into capacity-building and non-capacity-building components.

Second, although extensive conceptual literature discusses the importance of capacity-building for aid effectiveness, most focus is on its importance for overall governance capacity or climate adaptation capacity. Research on capacity-building in particular sectors is scarce, particularly within the energy sector (Kim, 2018). This will be addressed by focusing on capacity-building within renewable energy, specifically by analysing renewable energy aid and renewable energy consumption.

Lastly, existing literature has not examined low-income countries in isolation, instead often conducting research on specific geographical locations or on developing countries of all income levels. Yet, low-income countries are disproportionately affected by climate change despite their greenhouse gas emissions making up a small proportion of the global total (Bhargawa & Bhargava, 2023). Additionally, they lack substantial capacity necessary to fight the effects of climate change (Chen & He, 2013) and switch to renewable energy (Kim, 2018). These disadvantages make them particularly dependent on external support, such as renewable energy aid (IEA, 2024; Kim & Lee, 2021). This study will address this gap by focusing on low-income countries, where the potential impacts of renewable energy aid through capacity-building may be most critical.

2.3 Conceptualization

2.3.1 Renewable Energy Aid

Foreign aid refers to technical or financial assistance provided to recipient countries by foreign donors (Kretschmer et al., 2013; Villanthenkodath et al., 2022). Technical aid includes training, planning, assessment, and reviewing, while financial assistance refers to loans, bonds, and grants (Haque & Rashid, 2021). Various actors can be donors, including governments, institutions, or private entities (Long et al., 2024; Yang & Park, 2020). Moreover, commitments represent written obligations to provide aid with no guarantee of delivery, while disbursements include only aid that has been delivered (Kim, 2018). Renewable energy aid, then, is aid meant to support renewable energy (Kretschmer et al., 2013). It can target energy generation, distribution, policy and administration, education, or research (Bhattacharyya et al., 2018; Jain & Bardhan, 2024; Khan et al., 2024; Liu et al., 2023-a; Liu et al., 2023-b).

This study will consider financial renewable energy aid (RAID) disbursed by official donors. The focus is on RAID because literature often identifies it as conductive to energy decarbonisation. For validity reasons, only disbursements are considered as commitments may never be delivered and could distort results (Betzold, 2016). Lastly, only official donors are considered, which include governments and multilateral organisations (OECD, 2025), due to superior data availability and consistency of reporting (Tilley, 2024). Other donors such as NGOs and private contractors often fail to consistently record aid disbursements.

2.3.2 Capacity-Building

Capacity is commonly defined as "the ability of people, organisations, and society as a whole to manage their affairs successfully" (OECD, 2006, p.8). The UNDP (2009) expands this to include the ability to perform functions, solve problems, and achieve objectives. These abilities depend on both physical capital (e.g., equipment) and non-physical capital (e.g., skills and knowledge) (Kim, 2018). Capacity-building refers to the process of developing and strengthening these capabilities (Chen & He, 2013). Aid donors can support this by providing capital, for example by funding research and training.

In the context of this study, capacity-building specifically refers to enhancing a country's ability to adopt and maintain renewable energy technologies, expertise, and infrastructure (Kim, 2018). Focusing on capacity-building within renewable energy as opposed to, for example, within governance or climate adaptation more broadly, ensures that the concept remains aligned with renewable energy aid and renewable energy consumption, thereby improving conceptual precision and validity.

2.3.3 Renewable Energy Consumption

Renewable energy sources refer to sources which can be renewed in the human lifetime scale (Caetano et al., 2023). They include wind, solar, biomass and biofuel, hydroelectric, marine, geothermal, and nuclear (Villanthenkodath et al., 2022; Yang & Park, 2020). It is important to note that not all renewable sources are free of carbon emissions. Especially those relying on combustion of natural resources, namely biomass and biofuel, can still carry high environmental burden (Caetano et al., 2023). Thus, this study will not equate renewable energy consumption to energy decarbonisation.

The focus will be on renewable energy consumption within aid-recipient countries. This choice is based on common practice in previous research (Haque & Rashid, 2021; Liu et al., 2023-a; Naheed et al., 2024; Yang & Park, 2020). Additionally, data on renewable energy consumption is available as a clear indicator: "*renewable energy consumption (% of total final energy consumption)*" (World Bank Open Data, 2025). Other renewable energy indicators like renewable energy generation lack straightforward indicators and attempts at measuring them could weaken validity.

2.4 Hypotheses and Conceptual Model

Evidence on the relationship between aid and indicators of climate change mitigation is mixed for general aid and broader energy aid, with outcomes shaped by contextual factors like governance quality, absorptive capacity, and fossil fuel reliance. In contrast, studies focusing specifically on renewable energy aid (RAID) find more consistently positive effects on climate change mitigation indicators, frequently mediated by capacity-building mechanisms. These findings suggest that RAID may be especially effective in building capacity for renewable energy adoption, especially in low-income countries lacking more initial capacity. Therefore, this study hypothesizes a positive association between renewable energy aid and renewable energy consumption, mediated by capacity-building. Two hypotheses arise:

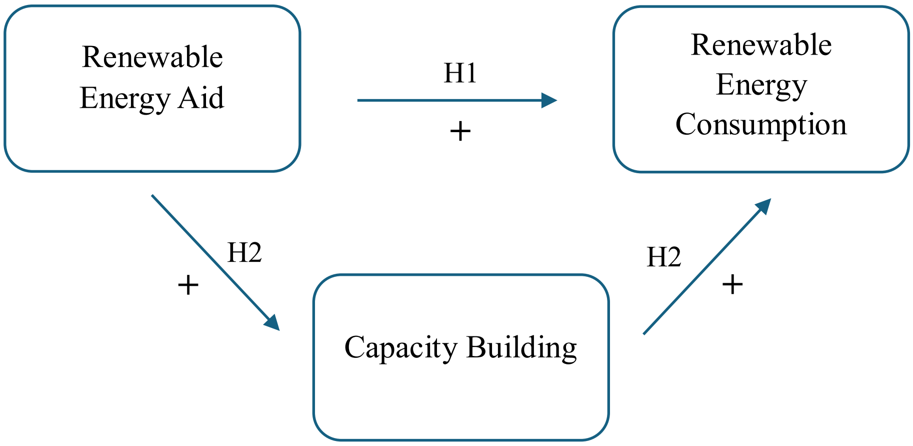
H1: Renewable energy aid is positively associated with renewable energy consumption.

H2: The positive association between renewable energy aid and renewable energy consumption is driven by capacity-building.

A visual model of these hypotheses is presented in the conceptual model below (Figure 1).

Figure 1

Conceptual Model



Confirming H1 is a necessary condition for H2 to be possible. However, even if H1 yields insignificant or contradictory results, disaggregating RAID into capacity-building and non-capacity-building components may reveal effects which are obscured when RAID is treated as a single measure. For instance, each component might have different effects on renewable energy consumption.

III. Methodology

To ensure reliability, this study's research procedures are outlined in detail to allow for replication. This section will first describe and justify the research design. Then, an explanation of the sample selection will be given. An operationalization will follow, defining how variables will be measured. The section will close with a description of the data analysis process.

3.1 Quantitative Research Design

This study employs a large-N panel linear regression analysis to examine the extent to which renewable energy aid (RAID) and its capacity-building components influence renewable energy consumption across low-income countries. Besides being the most common research design used in existing empirical studies, each component has positive implications for validity.

Large-N refers to datasets with a large number of entities (Thombs, 2022), providing the advantage of higher generalisability of findings (Flyvbjerg, 2006). Panel data, also called longitudinal data, consists of observations of the same entities over multiple time periods (Nguyen, 2020). Large-N panel data, thus, combines cross-sectional variation with time-series variation, providing exceptionally thorough data and increasing validity of findings. Lastly, a linear regression is a statistical method used to determine the character and strength of the relationship between a dependent variable and one or more independent variables (Beers, 2025). A large-N panel regression analysis is the most suitable research design for capturing how RAID, capacity-building, and renewable energy consumption relate to each other and evolve over time and across entities.

3.2 Sample Selection

The analysis will include data from 2010 to 2020. This timeframe is based on multiple considerations. First, this period avoids the distortive effects of the 2008 global financial crisis. Focusing on the more stable timeframe from 2010 to 2020 improves potential generalisability of findings. Second, this timeframe is recent enough to provide findings which are still relevant today, and its length allows for considering a time lag typically required for aid interventions to produce observable outcomes (Kim, 2018). Lastly, data availability is essential for a valid and complete sample. Several countries lack consistently available data before 2010 or after 2020, particularly for aid disbursements.

Regarding entities, this study observes RAID allocated to low-income countries. Though various definitions of low-income countries exist, a commonly accepted one is that of the World Bank. Countries are classified as low-, lower-middle-, upper-middle-, or high-income based on their nominal gross national income (GNI) per capita (World Bank, 2025). These classifications are meant to reflect not only income but also overall standard of living and development level (Metreau et al., 2024; World Population Review, 2025). Low-income countries are those whose GNI per capita, in 2023, was 1,145 US Dollars or less (World Bank, 2025). As of the 2025 fiscal year, this applies to 26 countries.

Countries with more than two consecutive years of missing data in any variable are excluded from the analysis to ensure reliable time-series comparisons. This is the case for Afghanistan, Eritrea, the Democratic People's Republic of Korea, South Sudan, and the Syrian Arab Republic. Data on these countries is lacking due to political instability and conflict, meaning their inclusion in the study would likely distort results and reduce validity. The final sample consists of 21 countries (Appendix A).

3.3 Operationalization

3.3.1 Renewable Energy Aid

This study considers financial RAID disbursed by all official donors. The data is retrieved from the OECD Creditor Reporting System (CRS) (OECD, 2025), which is used by nearly all existing studies measuring aid volumes. It provides information on all recorded aid projects, with detailed descriptions of each project such as its aim or source.

Several filters are applied within the CRS database to funnel the data. The time period spans from 2010 to 2020, and only official donors are considered. Recipients include the 21 low-income countries with sufficient data on all variables. Commitments are excluded, leaving only disbursements, expressed in constant US Dollar (USD) prices. All modalities, such as debt relief or project support, are included, as well as all channels like NGOs or multilateral organisations.

The last step is to filter by sector, namely energy. The remaining data must then be refined in Excel to exclude aid towards non-renewables. This is done by considering only those projects which, in their description or title, mention renewable-related terms (Table 1). For this purpose, a dummy variable (RE) is constructed, coded as 1 if projects include renewable terms and as 0 if they do not. This results in a dataset containing only aid targeting renewable energy.

Table 1

Renewable Energy Terms

Solar	Wind	Hydro	Geothermal	Biofuel	Nuclear	General
Solar	Wind	Hydro	Geothermal	Biofuel	Nuclear	Renewable
Photovoltaic		Marine	Ground	Biomass		Green
PV		Ocean		Bioenergy		Sustainable
		Tidal		Biogas		Clean
		Wave				Transition

Note: Spanish and French translations of all terms were also included to ensure project descriptions in these languages were not overlooked.

The list in table 1 list was developed by the author and is based on definitions and keywords used in academic literature (e.g., Villanthenkodath et al., 2022; Yang & Park, 2020). Creating codes based on existing theory forms a deductive approach, which facilitates replicability and enhances construct validity (Creswell & Poth, 2018). However, it also introduces subjectivity, as it requires interpretation and decisions on which terms to include.

Therefore, this study acknowledges a potential limitation of misclassifying projects due to vague or misunderstood descriptions.

3.3.2 Capacity-Building

Since it is expected that capacity-building is realised through RAID, capacity-building is measured by identifying RAID disbursements which include explicit capacity-building components. Again, word-based filtering is applied. Specifically, projects are considered to build capacity when their title or description include any of the terms found in table 2. Another dummy variable (CB) is created, coded as 1 when projects include capacity-building terms and coded as 0 when they do not. This allows to isolate the effects of capacity-building aid and non-capacity-building aid.

Table 2

Capacity-Building Terms

Training	Skill	Seminar
Education	Capacity	Technical assistance/support
Research	Workshop	Technical cooperation
Knowledge	Advice/Advise	Awareness
Innovation	Strengthen	Ability

Note: Spanish and French translations of all terms were also included to ensure project descriptions in these languages were not overlooked.

The list in table 2 was likewise developed by the author using key themes and concepts from the literature on aid and capacity development (Chen & He, 2013; Kim, 2018; OECD, 2006; UNDP, 2009). The same considerations for validity and reliability apply as for the coding of renewable energy terms.

3.3.3 Renewable Energy Consumption

Data on renewable energy consumption is retrieved from the World Bank Open Data repository (World Bank Open Data, 2025). The indicator used is "*renewable energy consumption (% of total final energy consumption)*", which represents the share of renewable energy in total final energy consumption. Recording renewable energy consumption in proportion to total energy consumption levels allows for drawing implications on the substitution of fossil fuels (Jain & Bardhan, 2024; Liu et al., 2023-a; Villanthenkodath et al., 2022).

3.3.4 Control Variables

Multiple control variables are considered to account for unit heterogeneity, specifically the diversity of countries' conditions independent from aid.

GDP per Capita

Data on gross domestic product (GDP) per capita is retrieved from the World Bank Open Data repository. Almost all studies investigating the effects of aid, regardless of their sectoral focus, control for GDP per capita. This indicator, expressed in current US Dollars, measures gross domestic product divided by midyear population (World Bank Open Data, 2015). It is included to account for differences in countries' economic development. Within the context of energy, higher income levels may be associated with greater productivity and thus lower energy intensity, which can influence renewable energy demand and countries' capacities for absorbing aid (Kretschmer et al., 2013). This may explain Kim's (2018) finding that countries with different income levels experience different effects of aid. Ultimately, controlling for GDP per capita allows to isolate the effect of RAID from broader economic conditions.

Foreign Direct Investment

Another frequent control variable is foreign direct investment (FDI). The indicator "*foreign direct investment, net inflows (% of GDP)*" is retrieved from the World Bank Open Data repository and defined as "the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor" (World Bank Open Data, 2025). Assessing this indicator allows to control for capacity transferred through the private sector as opposed to aid donors, ensuring that observed effects are not wrongfully attributed to aid (Kim, 2018).

Access to Electricity

A final control variable is the percentage of recipient countries' population with access to electricity. It is expected that low access to electricity may prompt more energy aid, especially to countries which focus on promoting renewables (Haque & Rashid, 2021). Including this indicator helps account for differences in energy needs and RAID demand, which may confound the relationship between RAID and renewable energy consumption.

3.4 Data Analysis

3.4.1 Panel Construction

The collected data is prepared in Excel. To obtain data on RAID, capacity-building RAID (CB RAID), and non-capacity-building RAID (non-CB RAID), data on total energy aid is filtered by applying the RE and CB dummy variables. Disbursements are then aggregated by country and year. The dependent variable, renewable energy consumption, and the control variables are also merged into the panel dataset. All variables are structured at the country-year level to ensure consistency with the panel format.

The panel is imported into SPSS (v28) for analysis. Prior to estimation, a one-year time lag is applied to RAID, CB RAID, non-CB RAID, and FDI, following common practice within literature. This accounts for the time typically required for aid and investment inflows to influence energy outcomes (Kim, 2018). Renewable energy consumption in year t is then linked to aid and FDI received in year $t–1$. A two-year lag is later tested as a robustness check. After lagging, RAID, CB RAID, and non-CB RAID are transformed using the natural logarithm to reduce skewness and the influence of extreme values (Htoon, 2020). This transformation reduces heterogeneity among variables and facilitates prediction of relationships between them (Naheed et al., 2024).

3.4.2 Regression Analysis

The main panel regression technique used in this study is a linear regression model, estimated using SPSS's General Linear Model procedure and including fixed effects for the country and year variables. Fixed effects are well-suited for analysing panel data where time-invariant differences between entities may influence outcomes. This approach controls for unobserved, unit-specific, time-invariant factors, such as geography or historical institutions (Wooldridge, 2010). Applying fixed effects reduces the risk of omitted variable bias, which can arise when standard statistical approaches attribute variation between units to observed variables, despite unmeasured factors influencing both the independent and dependent variables (Hill et al., 2019). This method is especially valuable in this study, where country-specific characteristics are likely to confound results.

In addition to the fixed effects model, a random effects model and a pooled ordinary least squares (OLS) model are estimated for comparison and robustness. Contrary to the fixed effects model, a random effects model assumes that changes in the dependent variable are uncorrelated with unobserved unit characteristics (Wooldridge, 2010). On the other hand, the pooled OLS model ignores unobserved unit-specific factors, assuming that all units have the same characteristics (Balgati et al., 2008).

All models are estimated using robust standard errors to correct for potential heteroskedasticity, which occurs when the variance of error terms is not constant over time (Hayes, 2024). Applying robust standard errors helps produce more reliable significance tests. Additionally, all results are reported as unstandardised coefficients, along with p-values, 95% confidence intervals, and partial Eta-squared values. Significance is assessed at the 1% and 5% levels. These reporting approaches facilitate comparison between models and allow for consistent interpretation of effect sizes and statistical significance. Lastly, R^2 values are examined to assess the proportion of variance in the dependent variable explained by each model.

IV. Results

This section will lay out the study's findings. First, a descriptive analysis will assess trends in each variable individually. Then, the regression analysis will outline how all variables relate to each other. Lastly, several robustness checks will be explained.

4.1 Descriptive Analysis

Before conducting a regression analysis, it is valuable to gain an overview of the individual variables and their trends. The following sections describe the means of the sample for each year between 2010 and 2020.

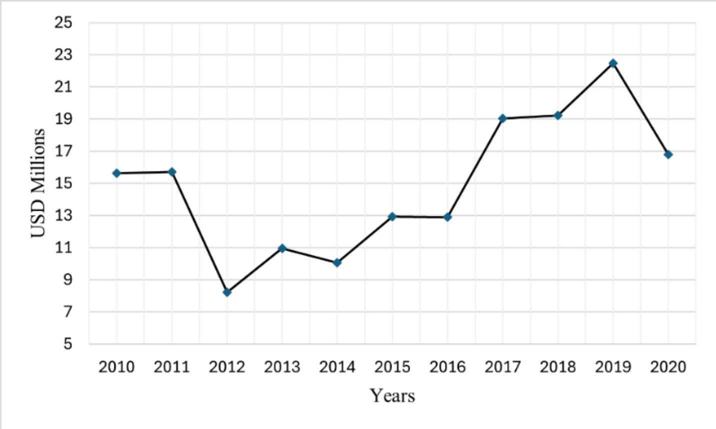
4.1.1 Renewable Energy Aid

The initial dataset, comprising all energy aid received by the sample from 2010 to 2020, consists of 5539 disbursements. Applying the RE dummy variable limits the dataset to disbursements targeting renewable energy. This results in 2101 RAID disbursements, making up 37.9% of all disbursements for this sample and time frame.

RAID experienced significant fluctuations between 2010 and 2020. 2010 and 2011 presented an initial stability, as development banks and other donors maintained consistent support as part of a post-2008 financial crisis stimulus (UNEP, 2010). This stability was disrupted in 2012, with values sharply declining from 15.7 million to 8.2 million USD (Figure 2). This reflects weakened markets and hesitant donors in the United States and Europe; major donors and investors for renewable energy (UNEP, 2013).

Figure 2

Renewable Energy Aid Trends



In the following years, RAID gradually recovered, suggesting renewed donor interest and international attention to aid for clean energy (Hydro Review Content Directors, 2020). A strong upward trend was then observed until a peak in 2019 at 22.5 million. This likely reflects growing international focus on climate adaptation and renewable energy in lower-income countries, resulting from global agendas like the Paris Agreement signed in 2015 (Kim & Lee, 2021). However, the 2020 value dropped again to 16.8 million, mainly due to Covid-19 disruptions which affected global financial flows and physical possibilities for project implementation (World Bank Group, 2022).

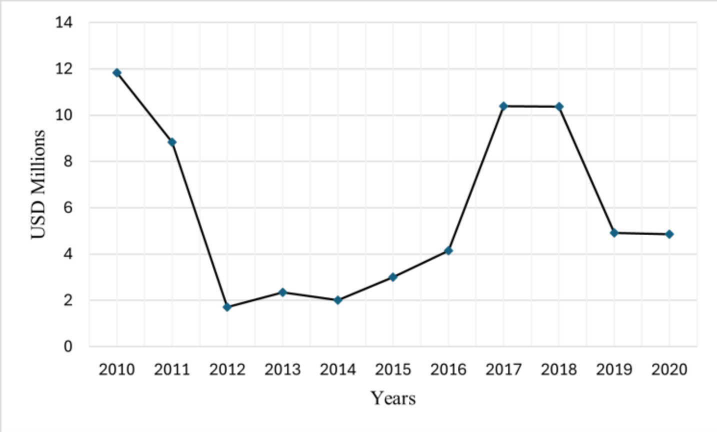
4.1.2 Capacity-Building RAID

To obtain values for renewable energy targeting capacity-building (CB RAID), the CB dummy variable is applied to the dataset of 2101 RAID disbursements. This results in 662 CB RAID disbursements, making up 31.5% of RAID, and only 11.9% of all energy aid.

Since CB RAID is a component of total RAID, both variables' trends can be compared. In 2010, out of 15.6 million USD in RAID disbursements, 11.8 million USD consisted of CB RAID (Figure 3). This strong focus on capacity-building for renewable energy was potentially a manifestation of a growing global focus on climate initiatives.

Figure 3

Capacity-Building Aid Trends



Disbursements then declined sharply in 2012, similarly to RAID. Again, this reflects weakened markets and hesitant donors concerned about the value of supporting renewable energy (UNEP, 2013). In the following years, CB RAID largely followed the same trend as RAID, but its share relative to total RAID disbursements was considerably smaller than in 2010. A potential explanation is a shift in donor focus on infrastructure and immediately visible outputs, as opposed to longer-term results from capacity building.

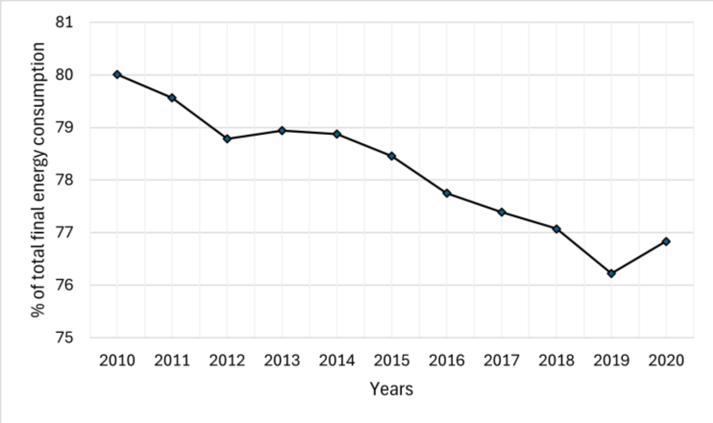
Then, 2017 figures sharply increased to 10.4 million USD, nearly reaching 2010 levels. Mirroring the peak of RAID, this was also attributable to an amplified focus on climate adaptation and support (Kim & Lee, 2021). Lastly, the effects of Covid-19 were also visible in CB RAID trends, with levels dipping to 4.8 million USD. In addition to disrupted global financial flows and limited physical possibilities for project implementation (World Bank Group, 2022), the pandemic caused a shift of aid priorities towards crisis response, reducing attention to longer-term and less urgent goals like capacity-building.

4.1.3 Renewable Energy Consumption

Low-income countries started with remarkably high levels of renewable energy consumption in relation to their total energy consumption, although these slightly declined over the decade. In 2010, mean renewable energy consumption levels were 80% (Figure 4), indicating that many low-income countries were heavily reliant on renewable energy sources. Still now, they rely predominantly on traditional biomass due to having limited access to modern energy grids (UNCTAD, 2017).

Figure 4

Renewable Energy Consumption Trends



Over the following years, a gradual decline was observed, with the lowest value of 76.2% in 2019. This implies a parallel increase in non-renewable energy consumption. Explaining this increase is significant economic growth and higher demand for energy (George-Ikoli & Sayne, 2024). In particular, economic growth improved access to modern energy grids which often run on fossil fuels. In addition, a growing economy requires more energy to maintain. To meet such increasing demands, low-income countries gradually expanded their reliance on non-renewable sources such as coal, oil, and natural gas for rapid scaling up.

Covid-19 also affected renewable energy consumption, as is visible in a slight uptick in 2020. A probable explanation is the pandemic's disruption to non-renewable energy supply chains, forcing low-income countries to temporarily return to traditional sources like biomass (Gordon, 2022).

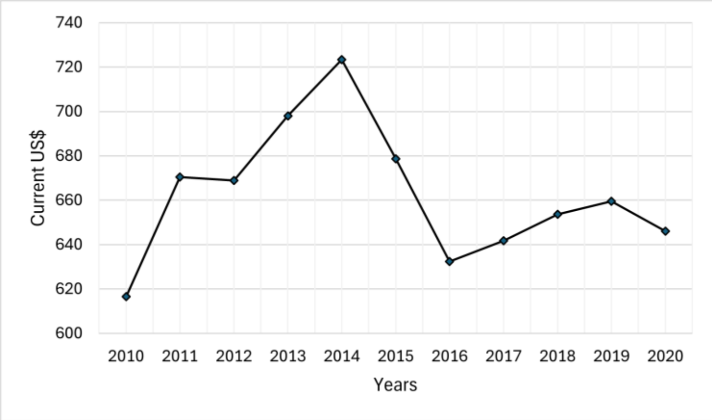
4.1.4 Control Variables

GDP per capita

Although GDP per capita levels remained extremely low throughout the decade, they fluctuated significantly. Starting at 616.6 USD in 2010, they rose steadily to 723.3 USD in 2014 (Figure 5), partly due to a commodity price boom that lasted into 2011 and remained elevated for years (Steinbach, 2019). Low-income countries, highly reliant on commodity exports, tend to mirror global commodity price trends. Many also received debt relief under international initiatives, reducing government debt.

Figure 5

GDP per Capita Trends



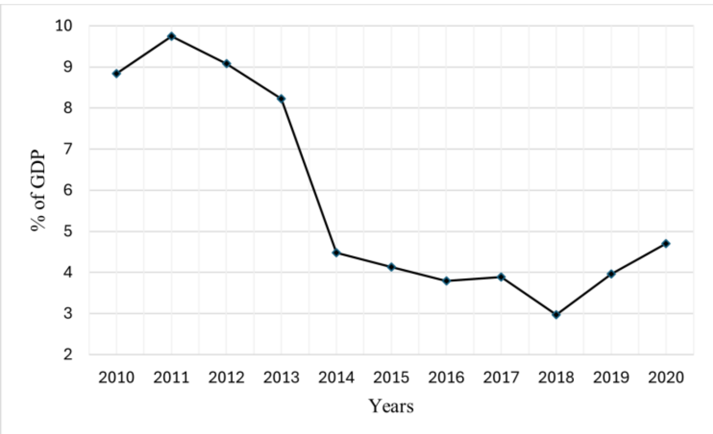
However, GDP per capita declined to 678.6 USD in 2015 and 632.4 USD in 2016, driven by a sharp commodity price crash from 2014 to 2016 (United Nations, 2019). Trade balances worsened and government debt began rising again as debt relief dwindled. Between 2017 and 2019, GDP per capita recovered moderately due to a partial price recovery, though debt remained high (Steinbach, 2019). A final decline to 646 USD in 2020 reflected early Covid-19 impacts. The pandemic triggered the worst economic performance in 30 years for low-income countries, reversing prior progress and exacerbating poverty while making development targets like the SDGs harder to reach (UNCTAD, 2020).

Foreign Direct Investment

Foreign direct investment (FDI) inflows were high at the beginning of the decade, peaking at 9.7% of GDP in 2011 (Figure 6). This post-financial crisis surge reflected historically low interest rates in high-income countries and stronger growth prospects in developing economies, making low-income countries attractive to investors (The World Bank, 2014).

Figure 6

Foreign Direct Investment Trends



Afterwards, FDI declined steadily, dropping to 4.4% in 2014 and reaching a low of 2.9% in 2018. A likely cause is the 2014–2016 commodity price crash, which reduced the profitability of resource-related investments, especially in commodity-dependent countries (United Nations, 2019). Simultaneously, rising government debt and falling GDP per capita increased macroeconomic risk and made low-income countries less attractive to investment (Nebe et al., 2024).

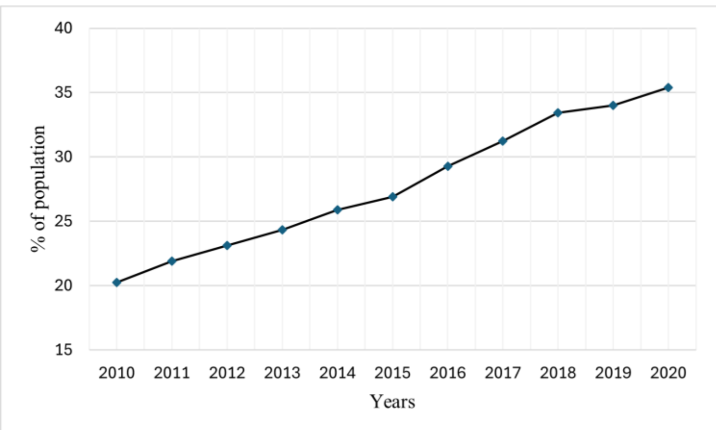
FDI inflows rose again in 2019 and 2020, ending the decade at 4.7% of GDP. This uptick may reflect gradual recovery in commodity prices, though FDI levels remained below pre-crash figures as government debt and macroeconomic risk persisted (Steinbach, 2019). Additionally, since the Covid-19 pandemic severely reduced GDP (UNCTAD, 2020), the increase in FDI-to-GDP ratio may partly reflect shrinking GDP rather than rising FDI.

Access to Electricity

Although access to electricity remained low over the decade, it rose steadily from 20.2% to 35.4% of the population (Figure 7). Most years saw gradual annual growth of just over one percentage point. From 2015 to 2018, access accelerated from 26.9% to 33.4%, a nearly 7-point gain in three years. This progress reflects the scaling-up of global initiatives like Sustainable Energy for All, launched by the UN in 2011 to support SDG7 (SEForAll, 2020), as well as national strategies focused on grid expansion and off-grid alternatives (IEA et al., 2020).

Figure 7

Access to Electricity Trends



Most improvements occurred in Sub-Saharan Africa and rural areas (IEA et al., 2020), which is highly relevant to this study, as all countries in the sample except Yemen are sub-

Saharan and have large rural populations. Lastly, growth slowed after 2019 as Covid-19 caused a shift in priorities for actors leading electrification efforts. They focused more on crisis response and healthcare support (SEForAll, 2020). The decade closed with 35.4% of the population with access to electricity.

4.2 Regression Analysis – Fixed Effects Model

<u>4.2.1 Hypothesis 1 – Renewable Energy Aid</u>

In order to test H1, which posits that RAID is positively associated with renewable energy consumption in low-income countries, a fixed effects linear regression model was estimated. Specifically, SPSS's General Linear Model procedure was applied with fixed effects for the country and year variables. Table 3 presents the results of this model.

Table 3

Fixed Effects Regression Results – Renewable Energy Aid

Variable	**Coefficient (B)**	**Robust Std. Error**	**t-value**	**p-value**	**95% CI (Lower-Upper)**	**Partial Eta^2**
RAID (lagged$_1$; logged)	-0.315	0.225	-1.404	0.162	[-0.759, 0.128]	0.011
GDP per capita	-0.002	0.001	-1.507	0.134	[-0.005, 0.001]	0.013
FDI (lagged$_1$)	-0.106	0.020	-5.328	<0.001*	[-0.146, -0.067]	0.140
Access to Electricity	-0.025	0.042	-0.598	0.550	[-0.107, 0.057]	0.002

**significant at the 1% level*

Fixed effects: Country and Year

R^2: 0.989 / Adjusted R^2: 0.986

Observations (N): 209

Each coefficient (B) represents the estimated effect of a variable on renewable energy consumption while holding all other variables constant. In testing H1, the main variable of interest is RAID and has a coefficient of –0.315. Since RAID has been log transformed, this means that a 1% increase in RAID leads to a 0.00315 percentage point decrease in renewable energy consumption (Lefcheck, 2021). However, the p-value for RAID is 0.162. P-values above 0.05 imply statistically insignificant results (Beers, 2024), thus the relationship between RAID and renewable energy consumption is insignificant. This is further highlighted by the 95% confidence interval of [−0.759, 0.128]. This interval's inclusion of zero means that the effect of RAID is not statistically significant at the 95% confidence level (Bobbitt, 2021). Lastly, the partial Eta^2 is 0.011, reflecting a small effect size (Bobbitt, 2022). In exact terms, RAID explains only 1.1% of variation in renewable energy consumption after accounting for other predictors (Bobbitt, 2022). Taken together, these findings suggest no evidence that RAID is significantly associated positively with renewable energy consumption within this sample and time frame. Thus, H1 is rejected.

In addition to the main independent variable, several other variables were included into the estimation to control for potential effects not accounted for by RAID. Beginning with GDP per capita, a coefficient of -0.002 suggests a weak negative relationship to renewable energy consumption. However, the corresponding p-value (0.134), as well as the confidence interval of [-0.005, 0.001] indicate statistical insignificance. The partial Eta^2 (0.013) confirms the small effect size. Thus, variation in GDP per capita cannot meaningfully explain changes in renewable energy consumption.

Another control variable, FDI, is the only variable in this model to present a significant association with renewable energy consumption. FDI is expressed in % of GDP and is not log-transformed, thus its coefficient must be interpreted differently from that of RAID. Here, a one percentage point increase in FDI leads to a decrease of 0.106 percentage points in renewable energy consumption. With a p-value below 0.001, this effect is significant at the 1% level, meaning there is a 1% probability that the observed data would occur if the null hypothesis were true. This significance is confirmed by the confidence interval [-0.146, -0.067], which does not include zero. Lastly, the partial Eta^2 of 0.140 represents the largest effect size within this model. These values indicate that FDI is an important driver of changes in renewable energy consumption, exerting a decreasing effect.

The last control variable, access to electricity, is very weakly ($B = -0.025$; partial $Eta^2 = 0.002$) and not significantly ($p = 0.550$; CI = [-0.107, 0.057]) associated with renewable energy consumption. This implies that changes in levels of electricity access do not predict shifts in renewable energy consumption.

To assess the performance of the model in its entirety, R^2 is a valuable indicator, as it represents the proportion of variance in the dependent variable which is explained by the independent variables (Fernando, 2024). Values can range from 0 to 1, where 0 means the model explains no variability and 1 means it explains all variability. This model has a very high R^2 of 0.989, meaning it explains 98.9% of the variation in renewable energy consumption within countries over time. Several results suggest that most of this explanatory power is attributable to country fixed effects, which control for time-invariant country characteristics. First, the above results indicate that the independent variable and most control variables have limited explanatory power. Second, the country fixed effects are all highly significant with large coefficients and high partial Eta^2 values (see SPSS output submitted separately). These results imply that the model's explanatory power lies primarily within the country fixed effects. This also justifies the use of a fixed effects regression model, as accounting for unobserved country-specific characteristics improves the model's ability to explain variation in renewable energy consumption. This further highlights the importance of time-invariant national factors and the importance of controlling for them to avoid omitted variable bias.

In summary, the fixed effects regression model including RAID does not support H1, as RAID does not show a positive or statistically significant relationship with renewable energy consumption. GDP per capita and access to electricity do not show significant results, while FDI demonstrates a significant negative effect. Country-fixed effects have strong explanatory power, making a fixed effects model suitable for this study.

4.2.2 Hypothesis 2 – Capacity-Building Aid and Non-Capacity-Building Aid

H2, which posits that the positive association between renewable energy aid and renewable energy consumption is driven by capacity-building, relies on the confirmation of H1. However, the analysis does not support H1. Despite this, testing H2 remains valuable, as it may help explain why RAID does not exert the expected positive effect on renewable energy consumption. The explanation may lie in the differing effects of RAID's capacity-building and non-capacity-building components. The same procedure as above was applied once for capacity-building aid and once for non-capacity-building aid.

Capacity-Building Aid

Within this model, CB RAID captures the capacity-building component of renewable energy aid and is the main variable of interest. CB RAID has also been log-transformed, so its coefficient of -0.613 indicates that a 1% increase in CB RAID is associated with a 0.00613 percentage point decrease in renewable energy consumption (Table 4). This negative relationship is statistically significant, as made clear by the p-value (0.002) indicating significance at the 1% level. The 95% confidence interval [-0.988, -0.0238] does not include zero, further reinforcing the statistical significance of the result. The partial Eta^2 value of 0.056 specifies a small effect size, though larger than that of GDP per capita or access to electricity. Thus, CB RAID is negatively and significantly associated with renewable energy consumption, counter to expectations of a positive relationship and not supporting H2.

Table 4

Fixed Effects Regression Results – Capacity-Building Aid

Variable	Coefficient (B)	Robust Std. Error	t-value	p-value	95% CI (Lower-Upper)	Partial Eta^2
CB RAID (lagged$_1$; logged)	-0.613	0.190	-3.225	0.002*	[-0.988, -0.238]	0.056
GDP per capita	-0.002	0.001	-1.734	0.085	[-0.005, 0.000]	0.017
FDI (lagged$_1$)	-0.110	0.019	-5.780	<0.001*	[-0.148, -0.073]	0.160
Access to Electricity	-0.030	0.040	-0.755	0.451	[-0.110, 0.049]	0.003

**significant at the 1% level*

Fixed effects: Country and Year

R^2: 0.989 / Adjusted R^2: 0.987

Observations (N): 209

The same control variables are tested here as they were in the previous model. Beginning with GDP per capita, its coefficient (-0.002) is equal to that in the previous model, again suggesting a weak negative association with renewable energy consumption. Similarly, it is also not statistically significant. Though having a lower p-value (0.085), as well as a confidence interval [–0.005, 0.000] narrowly including zero, these results still reflect marginal non-significance. The partial Eta^2 (0.017) is slightly higher than in the previous model yet signals a small effect size. Combined, these values cannot attribute meaningful predictive power to GDP per capita regarding variation in renewable energy consumption.

FDI again emerges as the strongest predictor in the model. Its coefficient is -0.110, indicating that a one percentage point increase in FDI is associated with a 0.110 percentage point decrease in renewable energy consumption. The relationship is significant at the 1% level, with a p-value below 0.001. The confidence interval [–0.148, –0.073] excludes zero, and the partial Eta^2 of 0.160 is the largest in the model, confirming the important negative effect of FDI on renewable energy consumption.

The final control variable, access to electricity, has the lowest partial Eta^2 (0.003) within this model and thus the smallest effect size. The low coefficient of -0.030 is statistically insignificant ($p = 0.451$; CI = [–0.110, 0.049]). These results suggest that variations in access to electricity cannot significantly explain changes in renewable energy consumption.

Assessing the overall model fit, this model's R^2 of 0.989 means that it has the same explanatory power as the previous one, being able to explain 98.9% of variation in renewable energy consumption. As with the previous model, this high explanatory power is primarily due to the country fixed effects. The choice of accounting for unobserved and time-invariant factors by applying fixed effects is further justified.

Finally, the fixed effects regression model including CB RAID does not support H2. While H1 was rejected, H2 is additionally contradicted, since CB RAID is significantly associated with a decrease, as opposed to an expected increase, in renewable energy consumption. GDP per capita and access to electricity are not significant predictors, while FDI again shows a strong and negative effect. The entire model has high explanatory power, mainly concentrated in the fixed effects.

Non-Capacity-Building Aid

As stated in the descriptive analysis, the studied sample consists of 2101 RAID disbursements. Of these, 662 target capacity-building, meaning that the remaining 1439 do not. Since these 1439 disbursements account for 68.5% of all RAID, it is essential to also test the effect of non-capacity-building aid (Non-CB RAID), as its predominance may help explain why aggregate RAID does not exhibit the expected positive influence on renewable energy consumption.

Non-CB RAID captures the component of RAID which does not target capacity-building and is the main variable of interest in this estimation. A coefficient of 0.108 suggests a weak positive association with renewable energy consumption (Table 5). Nevertheless, this association is not statistically significant ($p = 0.654$; CI = [-0.369, 0.586]). Additionally, the partial Eta^2 value is just 0.001, reflecting a very small effect size. Ultimately, non-CB RAID has no meaningful influence, either positive or negative, on renewable energy consumption.

Table 5

Fixed Effects Regression Results – Non-Capacity-Building Aid

Variable	Coefficient (B)	Robust Std. Error	t-value	p-value	95% CI (Lower-Upper)	Partial Eta^2
Non-CB-RAID (lagged$_1$; logged)	0.108	0.242	0.448	0.654	[-0.369, 0.586]	0.001
GDP per capita	-0.002	0.001	-1.509	0.133	[-0.005, 0.001]	0.013
FDI (lagged$_1$)	-0.096	0.020	-4.791	<0.001*	[-0.135, -0.056]	0.116
Access to electricity	-0.011	0.041	-0.272	0.786	[-0.093, 0.071]	0.000

**significant at the 1% level*

Fixed effects: Country and Year

R^2: 0.989 / Adjusted R^2: 0.986

Observations (N): 209

The control variables show similar results to those in the RAID and the CB RAID models. GDP per capita maintains a coefficient of -0.002, a statistically insignificant ($p = 0.133$; CI = [-0.005, 0.001]) weak negative relationship. Together with the low partial Eta^2 value (0.013), these findings reaffirm that GDP per capita does not meaningfully explain variation in renewable energy consumption.

Consistently showing a significant effect across all models is FDI, which here has a coefficient of -0.096. Though this indicates a slightly weaker effect compared to the other models, the negative association is highly significant at the 1% level, supported by a p-value <0.001 and a confidence interval [–0.135, –0.056] excluding zero. Once again, its partial Eta^2 of 0.116 is the largest in the model. Thus, the non-CB RAID model supports the reoccurring important negative effect that FDI has on renewable energy consumption.

Access to electricity remains the weakest predictor of variance in renewable energy consumption. In fact, within this model, it has the weakest explanatory power compared to the other models, reflected in a partial Eta^2 score of 0.000 which signifies no explanatory contribution. The coefficient of –0.011 and p-value of 0.786, along with a confidence interval of [–0.093, 0.071], all confirm that this variable does not significantly influence renewable energy consumption.

The overall model's R^2 value of 0.989 matches the previous models and is again mostly attributable to the country fixed effects rather than the independent or control variables. In summary, the fixed effects regression including non-CB RAID does not support H2. Unlike CB RAID, which is significantly associated with a decrease in renewable energy consumption, non-CB RAID has no significant positive or negative effect, as is the case for total RAID. GDP per capita and access to electricity remain non-significant, while FDI continues to show a significant negative association. As in previous models, most of the explanatory power comes from the country fixed effects, highlighting the importance of accounting for structural national differences across time.

4.3 Robustness Checks

To improve the validity of the findings, the regression is repeated with model variations. This uncovers whether the results are specific to the model used above or if they hold true under diverse conditions. Additionally, testing the same relationships under different conditions allows for comparisons and clarifies which model is most suitable for this study. The analysis was repeated with three models: a fixed effects model with a two-year lag for the aid variables and FDI; a random effects model; and a pooled OLS model.

4.3.1 Fixed Effects Model with Two-Year Lag

Within the main fixed effects model, a one-year time lag was applied to RAID, CB RAID, non-CB RAID, and FDI. This is common in literature and accounts for the time required for aid and investment flows to influence energy outcomes (Kim, 2018). However, there is no consensus on how large a time lag should be. Considering the failure of the tested model in confirming the hypotheses, it is possible that a time lag of one year is too short for the expected effects to be observed. To verify this, the same models are estimated with the aid and FDI variables lagged by two years, meaning that renewable energy consumption in year *t* is linked to aid and FDI received in year *t-2*.

The results are broadly consistent with the main analysis (Appendix B). In all models, access to electricity remains statistically insignificant with very low effect size. The largest effect size is still from FDI, a consistently strong and significant negative predictor. Interestingly, GDP per capita has a significant negative effect in all models, though with small effect size. This may suggest a delayed, modest negative association between GDP per capita and renewable energy consumption. The main variables of interest all exhibit the same effects as previously, with RAID and non-CB RAID having no significant relationship to renewable energy consumption, while CB RAID has a significant negative relationship, though still a smaller effect size than FDI. Lastly, the overall model fit remains very high, again attributable to the country fixed effects. Thus, a two-year time lag for the aid and FDI variables, though having revealed a weak negative association between GDP per capita and renewable energy consumption, remains constant in all other findings and does not confirm the hypotheses.

4.3.2 Random Effects Model

Because this study examines a sample of multiple countries, there is a risk of country-specific characteristics confounding results. To address this, the primary analysis applied a fixed effects model to control for unobserved time-invariant country characteristics (Wooldridge, 2010). In contrast, a random effects model assumes that changes in the dependent variable are uncorrelated with unobserved country characteristics. To test the appropriateness of the fixed effects approach, the studied relationships were re-estimated using a random effects model for comparison.

The results from the random effects analysis generally mirror those of the fixed effects analysis (Appendix C). Across all models, FDI is a statistically significant predictor and negatively associated with renewable energy consumption. Access to electricity and GDP per capita continue to have low explanatory power and no significance. Regarding the main variables of interest, RAID and non-CB RAID again show no significant association, whereas CB RAID maintains a significant negative relationship to renewable energy consumption. Thus, all independent and control variables show similar results for random effects models as they did in the main fixed effects models.

As for model suitability, the residual variance is much lower than the intercept variance attributed to countries, indicating that most variation in renewable energy consumption comes from differences between countries, rather than within them over time. This could suggest that time-invariant, country-specific factors are highly influential, further justifying the use of fixed effects to account for these factors. Ultimately, these results improve the robustness of the main findings and continue to contradict both hypotheses.

4.3.3 Pooled OLS Model

For further comparison, the studied relationships were again estimated using a pooled OLS model, which ignores unobserved unit-specific factors altogether (Balgati et al., 2008). These pooled regressions produced vastly different results compared to previous models (Appendix

D). Most notably, the main variables of interest – RAID, CB RAID, and non-CB RAID – all show significant positive relationships with renewable energy consumption. This contrasts with previous models, where RAID and non-CB RAID had no significant effects and CB RAID had a significant negative effect. Moreover, GDP per capita is significant in all pooled models, as it was in the two-year lag fixed effects models but not in the one-year lag fixed effects or the random effects models. Another difference is access to electricity, here significantly negatively associated with renewable energy consumption. Furthermore, FDI shows no significant effect in any pooled model, contradicting all other estimation model findings.

In terms of model fit, the three models explain roughly 47-50% of variation in renewable energy consumption; much lower values than the other models. These lower values for model fit, as well as the vastly different findings for individual variables, are likely due to omitted variable bias. This is because pooled OLS does not account for time-invariant country-level factors, instead assuming independence of observations. This highlights the importance of accounting for country heterogeneity by fixing country effects.

4.4 Summary of Regression Findings

The fixed effects regression models do not support either hypothesis. RAID shows no significant relationship with renewable energy consumption, thereby rejecting H1. When RAID is disaggregated, CB RAID is significantly and negatively associated with renewable energy consumption, directly contradicting H2. Non-CB RAID, like total RAID, also shows no significant effect. Across all fixed effects models, GDP per capita and access to electricity remain non-significant, while FDI consistently demonstrates a significant negative effect. The strong explanatory power of these models lies in the country-fixed effects, indicating that time-invariant national differences, rather than temporal variation, are key drivers of renewable energy consumption.

Robustness checks using a two-year lag and random effects confirm the main results. The two-year lag introduces a weak negative association between GDP per capita and renewable energy consumption but does not change other conclusions. The random effects models also align with fixed effects results, and model diagnostics indicate that fixed effects are more appropriate due to the dominance of between-country variation.

Pooled OLS models, by contrast, produce significantly different results. RAID, CB RAID, and non-CB RAID all appear to positively affect renewable energy consumption. However, these models ignore time-invariant country characteristics, likely introducing omitted variable bias. This divergence highlights the importance of accounting for country-specific effects when analysing aid effectiveness.

V. Discussion

This study aimed to investigate whether renewable energy aid is associated with renewable energy consumption in low-income countries, and whether this relationship is driven by capacity-building. These hypotheses were based on existing literature yet are not supported by the findings of this study. The following sections will discuss potential explanations to the findings by connecting them to theory and research limitations.

5.1 Interpretation of Findings

The regression results contradict theoretical expectations regarding renewable energy aid and capacity-building in promoting renewable energy consumption. H1 posited that RAID is positively associated with renewable energy consumption, while H2 proposed that this relationship is driven by capacity-building. These hypotheses were grounded in vast literature finding that RAID improves climate mitigation outcomes through mechanisms like institutional strengthening, skill development, and technology transfer (Chapel, 2021; Haque & Rashid, 2021; Khan et al., 2024; Kim, 2018; Liu et al., 2023-a; Liu et al., 2023-b; Naheed et al., 2024; Yang & Park, 2020). However, the regression models found no significant effects for RAID, and a negative effect for its capacity-building component, not supporting the hypotheses.

An examination of the theory reveals the importance of contextual conditions in shaping renewable energy outcomes and may explain the failure of this study to confirm the hypotheses. Several authors emphasise that recipient countries' conditions impact the effectiveness of aid and capacity-building. These include, for instance, absorptive capacity, political regimes, and policy environment (Yang & Park, 2020). Kim (2018) and Ikegami and Wang (2021) also discovered that a country's baseline of capacity and richness in fossil fuels condition outcomes, with lower capacity and lower fossil fuel ownership experiencing more positive effects of aid and capacity-building. Furthermore, conditions which have a generally dampening effect on the effectiveness of aid and capacity-building are weak governance institutions, excessive reliance on aid, and weak private and financial sectors (Farooq, 2021; Naheed et al., 2024). Lastly, Chen and He (2013) also emphasised donor conditions which improve the success of capacity-building efforts, such as monitoring and evaluation, efforts targeting policy, and demand-driven programmes tailored to recipients. The importance of contextual conditions in shaping aid and capacity-building effectiveness is supported by the strong explanatory power of country fixed effects across the regression models. Their dominant contribution to explaining variance in renewable energy consumption indicates that country-specific conditions and differences between countries, rather than year-to-year changes in aid flows, influence renewable energy outcomes.

Another potential explanation for the rejected hypotheses is the significant and negative association between foreign direct investment and renewable energy consumption, consistent across all fixed and random effect models. FDI plays an especially important role in low-income countries, as demonstrated by its high volumes during the studied timeframe (Figure 6). Behind the strong negative association between FDI and renewable energy consumption might lie FDI's frequent focus on resource extraction and non-renewable energy investments in low-income and resource-rich countries (Medlock & Miller, 2020). Such investments into non-renewable energy might dilute or reverse effects from RAID, especially if aid project conditions are weak.

The descriptive analysis further supports these interpretations. Substantial improvements in access to electricity and GDP per capita in some years, as well as occasionally high RAID and CB RAID inflows, were not accompanied by higher renewable energy consumption. This suggests strong influence from other, unobserved factors. Ultimately, this study mainly measured aid volume and intent. However, theory and findings suggest that aid effectiveness in increasing renewable energy consumption is significantly shaped by contextual conditions like national incentives, policy environments, and existing capacity.

5.2 Research Limitations

Despite efforts to ensure validity, reliability, and robustness, this study faced several limitations which may have contributed to its inability to confirm the hypotheses. Beginning with sample-related issues, data for variables like renewable energy consumption and access to electricity relies on national government reporting. Low-income countries, however, may have limited measurement and reporting capacity, affecting data quality. While this study partially addressed this risk by excluding countries with more than two consecutive years of missing data, there is no guarantee that data from the included countries is fully accurate. However, this concern also applies to much of the existing literature, where large samples are frequently used without excluding conflict-affected or authoritarian states. These differences in sample selection may help explain why this study's results diverge from expectations.

Another sample-related limitation is the 2010-2020 time frame, which is shorter than in most existing studies. This decision was due to time constraints in analysing additional years of data, but it may have limited the ability to observe longer-term effects. Related to this, one- and two-year lags for the FDI and aid variables might not be long enough to capture their delayed impacts on renewable energy consumption.

The scope of aid considered was also restricted to financial disbursements from official donors. While this choice was based on data quality and availability, it overlooks non-financial and non-official aid, which might affect renewable energy outcomes. Furthermore, although the study's exclusive focus on low-income countries addressed a literature gap, it also limits the generalisability of findings.

In terms of methodological choices, identifying RAID and CB RAID relied on keyword-based coding of project descriptions. Although the coding scheme was based on theory, it required subjective judgment from the author on which terms to include. Projects may also have been misclassified due to vague or incomplete project descriptions. Additionally, capacity-building was operationalised as a binary variable, not measuring intensity which could better explain outcomes. Lastly, RAID, CB RAID, and non-CB RAID were analysed in separate regression models. While this allowed to isolate their individual effects on renewable energy consumption, it neglects a potential correlation between them, risking omitted variable bias.

VI. Conclusion and Recommendations

6.1 Conclusion

This study aimed to answer the research question: *To what extent does capacity-building drive the association between renewable energy aid and renewable energy consumption in low-income countries?* A review of existing literature on the topic led to the formulation of two hypotheses:

H1: Renewable energy aid is positively associated with renewable energy consumption.

H2: The positive association between renewable energy aid and renewable energy consumption is driven by capacity-building.

These hypotheses were tested using a large-N panel regression analysis; however, they were not supported by empirical findings. Concerning H1, no significant effect was observed between RAID and renewable energy consumption. H2 could also not be supported, as the association between CB RAID and renewable energy consumption was significant and negative, rather than positive. These results prompted a reflection into potential factors affecting the study outcome, namely unobserved contextual factors, unexpected significant influence from FDI, and limitations within the study.

A central finding across all models was the strong explanatory power of country fixed effects, which highlight the importance of accounting for country-specific, time-invariant characteristics. Most variance in renewable energy consumption was explained by these characteristics, rather than variations in aid flows. This supports existing findings that aid outcomes are not only shaped by aid volume, but also conditioned by recipient countries' contexts (Farooq, 2021; Ikegami & Wang, 2021; Kim, 2018; Naheed et al., 2024; Yang & Park, 2020) and donor's actions in designing and implementing aid (Chen & He, 2013).

Moreover, FDI was significantly and negatively associated with renewable energy consumption across all main regressions, highlighting the influence of private sector financial flows on renewable energy outcomes. Within this study, potential positive effects of RAID and CB RAID might have been diluted by FDI, suggesting that the effectiveness of aid depends not only on its content or capacity-building features but also on how it interacts with broader influences like private sector financing.

This study had several limitations, some of which may help explain why the hypotheses were not confirmed. First, key variables relied on potentially inaccurate nationally reported data, raising concerns about data reliability. Additionally, the one- and two-year lags applied to aid and FDI may have been too short to capture their delayed effects. The study's short timeframe may have also limited the detection of long-term effects. Additionally, comparability with existing literature was limited by this study's exclusive focus on low-income countries and official donor disbursements, which limit generalisability. Methodologically, renewable energy aid and capacity-building aid were identified through a keyword-based coding scheme developed by the author. Although theory-based, this involved subjective choices and allowed for misclassifications. Finally, the aid variables were tested in separate regression models, which may have introduced omitted variable bias due to potential correlations between them.

Combining these insights to answer the research question, this study found that capacity-building does not drive the positive relationship between renewable energy aid and renewable energy consumption in low-income countries. In fact, no significant relationship between RAID and renewable energy consumption was observed, and CB RAID exerted a negative instead of a positive effect. Country-specific contexts and FDI explained more of the variation in renewable energy aid than did aid flows, highlighting the importance of considering how aid interacts with other factors in recipient countries.

6.2 Research and Policy Recommendations

Considering this study's limitations and findings, several recommendations are given for research. Future studies should use longer timeframes and incorporate longer time lags to ensure that potentially delayed effects of aid and capacity-building are fully captured. Furthermore, this study's approach to classifying projects by applying keyword-based coding could be refined to reduce subjectivity, for instance by creating a coding scheme based on frequency of keywords in relevant literature. Building upon this study's novel approach, capacity-building could also be operationalised in a more nuanced way, using scaled instead of binary measures to capture variation in intensity. Another possibility is to supplement or even replace statistical analysis with qualitative methods, for instance through in-depth case studies which might offer deeper insights into the contextual factors which were influential yet not measured in this study. A qualitative or mixed-method approach would also allow for assessing non-financial aid. Lastly, future studies should also examine how different aid variables interact, and how these interact with FDI flows.

This study also has implications for policymaking. Combined with insights from existing theory, it is clear that the effectiveness of aid and capacity-building is influenced by recipient countries' contexts, as well as aid focus and design. Accordingly, donors should tailor RAID and capacity-building efforts to countries' needs and demands, considering their existing energy structures and capacities, but also existing policy environments and national investment priorities. In addition, aid programs should include extensive monitoring and evaluation over longer periods of time. This would allow donors to adjust project aims and design, which could improve long-term effectiveness and in turn make future aid more effective. Moreover, considering the strong effect of FDI in this study, donors should seek to improve alignment with foreign investment trends. This would prevent FDI from undermining renewable aid efforts, resulting in more efficiently allocated resources.

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Appendices

Appendix A

Table 6

Study Sample

Burkina Faso	Guinea-Bissau	Rwanda
Burundi	Liberia	Sierra Leone
Central African Republic	Madagascar	Somalia
Chad	Malawi	Sudan
Democratic Republic of Congo	Mali	Togo
Ethiopia	Mozambique	Uganda
Gambia	Niger	Yemen

Appendix B

Table 7

Two-Year Lag Fixed Effects Results – Renewable Energy Aid

Variable	Coefficient B	Robust Std. Error	t-value	p-value	95% CI (Lower-Upper)	Partial Eta^2
RAID ($lagged_2$; logged)	-0.341	0.233	-1.530	0.128	[-0.781, 0.099]	0.015
GDP per capita	-0.003	0.001	-2.023	0.045**	[-0.006, -6.862E-5]	0.026
FDI ($lagged_2$)	-0.102	0.019	-5.278	<0.001*	[-0.141, -0.064]	0.152
Access to electricity	-0.032	0.042	-0.744	0.458	[-0.115, 0.052]	0.004

**significant at the 1% level* **significant at the 5% level

Fixed effects: Country and Year

R^2: 0.991 / Adjusted R^2: 0.989

Observations (N): 188

Table 8

Two-Year Lag Fixed Effects Results – Capacity-Building Aid

Variable	Coefficient B	Robust Std. Error	t-value	p-value	95% CI (Lower-Upper)	Partial Eta^2
CB RAID (lagged$_2$; logged)	-0.523	0.184	-2.851	0.005*	[-0.886, -0.161]	0.050
GDP per capita	-0.003	0.001	-2.035	0.044**	[-0.006, -8.509E-5]	0.026
FDI (lagged$_2$)	-0.105	0.019	-5.667	<0.001*	[-0.142, -0.069]	0.172
Access to electricity	-0.037	0.041	-0.914	0.362	[-0.118, 0.043]	0.005

**significant at the 1% level* ***significant at the 5% level*

Fixed effects: Country and Year

R^2: 0.991 / Adjusted R^2: 0.989

Observations (N): 188

Table 9

Two-Year Lag Fixed Effects Results – Non-Capacity-Building Aid

Variable	Coefficient B	Robust Std. Error	t-value	p-value	95% CI (Lower-Upper)	Partial Eta^2
Non-CB RAID (lagged$_2$; logged)	0.076	0.248	0.306	0.760	[-0.413, 0.565]	0.001
GDP per capita	-0.003	0.001	-2.015	0.046**	[-0.006, -5.850E-5]	0.026

FDI (lagged$_2$)	-0.091	0.020	-4.668	<0.001*	[-0.130, -0.053]	0.123
Access to electricity	-0.012	0.042	-0.287	0.775	[-0.094, 0.070]	0.001

**significant at the 1% level* ***significant at the 5% level*

Fixed effects: Country and Year

R^2: 0.990 / Adjusted R^2: 0.988

Observations (N): 188

Appendix C

Table 10

Random Effects Results – Renewable Energy Aid

Variable	F-value	p-value
Intercept	306.433	<0.001*
RAID (lagged$_1$; logged)	1.834	0.177
GDP per capita	2.581	0.110
FDI (lagged$_1$)	28.333	0.001*
Access to electricity	0.964	0.327
Year	2.127	0.030**

**significant at the 1% level* ***significant at the 5% level*

Random effects: Country

Intercept (subject = Country) Variance: 407.66

Residual variance: 5.52

Observations (N): 209

Table 11

Random Effects Results – Capacity-Building Aid

Variable	F-value	p-value
Intercept	315.545	<0.001*
CB RAID (lagged$_1$; logged)	10.340	0.002*
GDP per capita	3.349	0.069
FDI (lagged$_1$)	33.473	<0.001*

Access to electricity	1.304	0.255
Year	2.606	0.008*

**significant at the 1% level*

Random effects: Country

Intercept (subject = Country) Variance: 406.33

Residual variance: 5.27

Observations (N): 209

Table 12

Random Effects Results – Non-Capacity-Building Aid

Variable	F-value	p-value
Intercept	303.163	<0.001*
Non-CB RAID (lagged$_1$; logged)	0.271	0.604
GDP per capita	2.604	0.108
FDI (lagged$_1$)	22.873	<0.001*
Access to electricity	0.443	0.506
Year	2.606	0.008*

**significant at the 1% level*

Random effects: Country

Intercept (subject = Country) Variance: 403.26

Residual variance: 5.58

Observations (N): 209

Appendix D

Table 13

Pooled OLS Results – Renewable Energy Aid

Variable	Coefficient (B)	t-value	p-value
RAID (lagged$_1$; logged)	3.291	4.519	<0.001*
GDP per capita	-0.026	-5.366	<0.001*
FDI (lagged$_1$)	0.023	0.276	0.783
Access to electricity	-0.505	-7.853	<0.001*

**significant at the 1% level*

R^2: 0.495 / Adjusted R^2: 0.486

Regression: F = 50.089, $p < 0.001$

Observations (N): 209

Table 14

Pooled OLS Results – Capacity-Building Aid

Variable	Coefficient (B)	t-value	p-value
CB RAID (lagged$_1$; logged)	2.624	3.053	0.003*
GDP per capita	-0.028	-5.497	<0.001*
FDI (lagged$_1$)	0.016	0.187	0.852
Access to electricity	-0.525	-8.000	<0.001*

**significant at the 1% level*

R^2: 0.469 / Adjusted R^2: 0.459

Regression: F = 45.091, $p < 0.001$

Observations (N): 209

Table 15

Pooled OLS Results – Non-Capacity-Building Aid

Variable	Coefficient (B)	t-value	p-value
Non-CB RAID (lagged$_1$; logged)	3.569	4.371	<0.001*
GDP per capita	-0.026	-5.352	<0.001*
FDI (lagged$_1$)	0.027	0.328	0.743
Access to electricity	-0.510	-7.917	<0.001*

**significant at the 1% level*

R^2: 0.493 / Adjusted R^2: 0.483

Regression: F = 49.497, $p < 0.001$

Observations (N): 209