Consequences of the energy transition on poverty: evidence from the Southern African Development Community

VERSÃO FINAL APÓS DEFESA

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(Assinatura)

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Dedication

I dedicate this work to my parents, Agostinho Lucamba (in memory) and Faustina Henriqueta Capamalã.

Acknowledgement

I would like to express my deepest gratitude to all those who, in one way or another, have contributed to making this dream (of becoming a master's in economics) a reality. To my supervisor, Full Professor António Cardoso Marques, and my co-supervisor, Professor Diogo André dos Santos Pereira, for their feedback and reflections that made all the difference in realizing this dissertation.

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In the words of Professor António C. Marques, "I hope you all enjoy reading this dissertation as much as I enjoyed writing it.

Resumo

A literatura sobre as consequências da transição energética na pobreza nos países da Comunidade de Desenvolvimento da África Austral (SADC) é escassa. Esta dissertação tem como objetivo preencher esta lacuna, estudando as consequências da transição energética na pobreza energética e na pobreza tradicional. Para isso esta dissertação estudou 15 dos 16 países da SADC, desde 2000 até 2020, através dos modelos *autoregressive distributed* lag. Os resultados desta dissertação indicam que o consumo de energia limpa para cozinhar, por exemplo, as energias renováveis provenientes dos painéis solares fotovoltaicos, reduzem a pobreza energética nos países da SADC. Ademais, os resultados desta dissertação destacam ainda que as a utilização dos combustíveis fósseis como o carvão vegetal e a biomassa/lenha, (fontes de energia mais utilizadas na região da SADC), contribuem para reduzir a pobreza tradicional dos agregados familiares. No entanto, temos de salientar que estes combustíveis resultam em poluição. Este facto revela a necessidade dos países membros da SADC de políticas públicas concretas para proporcionar às suas populações um melhor acesso a fontes de energia sustentáveis e modernas. Assim, os resultados desta dissertação consideram que os investimentos em fontes de energia renováveis, por exemplo, através de painéis solares fotovoltaicos, podem contribuir para aumentar o acesso à eletricidade sem agravar ainda mais a pobreza tradicional e energética.

Palavras-chave: Pobreza energética, Transição energética, Comunidade de Desenvolvimento da África Austral, Consumo de energia para cozinhar, acesso à eletricidade.

Resumo Alargado

A necessidade de uma transição energética equilibrada e justa, é crucial para reduzir a pobreza energética e pobreza tradicional, protegendo principalmente as famílias mais vulneráveis. Os países da Comunidade de Desenvolvimento da África Austral (SADC) enfrentam grandes desafios no que concerne à falta de acesso à eletricidade, prova disto são os índices de pobreza energética. Segundo os dados do Banco Mundial, em 2022, 61% da população total da SADC ainda não dispões de acesso à rede elétrica.

A região da SADC tem 16 países membros, com uma grande diversidade nas suas características demográficas e socioeconómicas. O principal objetivo deste grupo de países consiste em alcançar o desenvolvimento económico, paz, segurança, crescimento económico, aliviar a pobreza, melhorar o padrão e a qualidade de vida dos povos da África Austral, e apoiar os socialmente desfavorecidos por meio da integração regional. Um fator importante a ter em conta é que à medida que a região da SADC se industrializa, a produção e distribuição de energia torna-se ainda mais importante. Daí surge a grande preocupação com a falta de acesso à eletricidade que, tem como consequência o aumento da pobreza energética e tradicional.

O primeiro conceito de pobreza energética analisou a mesma de uma perspetiva económica. Neste é afirmado que a pobreza energética, denota a incapacidade de um indivíduo ou família para fazer face aos custos com a energia. É preciso realçar que a literatura ainda não encontrou uma definição consensual para a pobreza energética. Pois, o seu conceito depende do contexto de análise. No contexto dos países em desenvolvimento, como é o caso dos países da SADC, a pobreza energética tem sido rotulada como a falta de acesso a infraestruturas energéticas (principalmente a falta de acesso à rede elétrica) para servir as populações, e o baixo uso de fontes de energias modernas e limpas.

Este estudo tem como objetivo analisar o impacto da transição energética na pobreza, com foco na pobreza energética e pobreza tradicional. Uma vez que a maneira como tem sido conduzida a transição energética, tem agravado a situação socioeconómica das famílias mais vulneráveis dos países em estudo. Por isso, esta dissertação levanta as seguintes questões de investigação: (i) a transição energética está a aliviar a pobreza energética e a pobreza tradicional nos países da SADC? (ii) o acesso à eletricidade está a contribuir para a redução da pobreza tradicional na SADC? e (iii) como é que os hábitos de consumo de energia para cozinhar têm impactado a pobreza tradicional e energética?

Para responder às questões de investigação, foram utilizados dados anuais de 2000 a 2020, para um conjunto de 15 dos 16 países da SADC (notar que Seychelles foi excluído devido à falta de dados em algumas variáveis indispensáveis para este estudo). Os dados foram retirados de duas bases de dados nomeadamente, Banco Mundial e Organização Mundial da Saúde. Para medir o impacto da transição energética na pobreza energética e na pobreza tradicional, dois grupos de modelos foram desenvolvidos (modelos de pobreza energética e modelos de pobreza tradicional). A pobreza tradicional foi mensurada através dos seguintes indicadores percentagem do rendimento das famílias, *Gini per capita*, e percentagem população empregada com mais de 15 anos de idade abaixo da linha de pobreza internacional. Por sua vez, a pobreza energética foi medida através da percentagem de pessoas que utilizam energia limpa para cozinhar, percentagem da população que utiliza energia fóssil para cozinhar e percentagem da população com acesso à eletricidade.

O impacto da transição energética na pobreza energética e tradicional foi analisado através das seguintes variáveis: percentagem da população que utiliza o carvão para cozinhar, percentagem da população que utiliza o kerosone para cozinhar, percentagem da população que utiliza o gás para cozinhar, percentagem da população que utiliza o *charcoal* para cozinhar, percentagem da população que utiliza o biomassa para cozinhar, percentagem da população que utiliza eletricidade para cozinhar, contribuição das energia renováveis para a matriz energética, intensidade energética, Produto Interno Bruto *per capita*.

Foi analisada matriz das correlações e as estatísticas *variance Inflation factos (VIF)*, cujo resultados mostram que não há existência de problemas de colineariedade e multicolineariedade. De seguida realizou-se o teste de dependência de secção transversal (*cross-section dependence*) e os testes de raízes unitárias. Apenas os testes de raízes unitárias de segunda geração foram aplicados uma vez que se verificou a dependência de secção transversal. Os testes de raízes unitárias evidenciaram uma ordem de integração mista entre as variáveis utilizadas neste estudo. Por outras, palavras umas variáveis eram integradas de ordem zero, e outras integradas de ordem um. No entanto, é de realçar que nenhuma era integrada de ordem dois ou superior. Por isso, considera-se adequada a utilização do modelo *Autoregressive Distributed Lag* (ARDL).

Após a análise dos testes de especificação, verificou-se a existência heterocedasticidade e autocorrelação de primeira ordem revelando assim o estimador Driscoll-Kraay como o mais apropriado para estimar os modelos *ARDL*. De salientar que a metodologia ARDL permite dividir o impacto total em efeitos de curto-prazo e de longo-prazo, permitindo analisar os efeitos em dois momentos diferentes.

Os resultados desta investigação revelam que a implementação das fontes de energias renováveis (FER) no mix de produção de eletricidade nos países da SADC, reduz a pobreza energética e tradicional. Esta redução da pobreza energética é resultante principalmente da energia solar fotovoltaica e eólica. De salientar que a região da SADC dispõe de um elevado potencial de produção de eletricidade a partir de painéis solares fotovoltaicos. Ademais, a produção descentralizada das FER podem aumentar o acesso à eletricidade em locais remotos (se ligada a redes locais ou a micro-redes). As FER podem ainda permitir outros benefícios, tais como: a redução do preço da eletricidade (uma vez que o sol é um recurso endógeno abundante na região da SADC), criação de emprego, e o acesso a energia limpa para cozinhar fora da rede nacional.

Esta investigação revela também o grande perigo que, a biomassa/lenha e o carvão/carvão vegetal estão a causar à saúde das famílias, levando mesmo à morte de crianças e adultos. O consumo destes combustíveis fósseis para cozinhar reduz a pobreza tradicional. Isto acontece porque estas formas de energia estão disponíveis a preços baixos e são frequentemente utilizadas por agregados familiares vulneráveis. Neste caso, é importante salientar que a transição energética na SADC para formas de energia modernas e limpas pode reduzir a pobreza energética e tradicional, pelo que a falta de acesso à eletricidade, e a dificuldade na obtenção de financiamento para implementar as FER constituem obstáculos para a transição energética.

Em suma, as políticas energéticas na região da SADC devem evoluir no sentido de reduzir a pobreza energética entre os agregados familiares mais vulneráveis, sem prejudicar a pobreza tradicional (que já regista níveis elevados nesta região). Assim, os governos dos países da SADC devem desenvolver projetos para aumentar a literacia energética, informando a sociedade sobre os impactos nocivos dos combustíveis fósseis no ambiente e na poluição interior das habitações, e os benefícios do consumo de eletricidade gerada por FER. Os países da SADC também devem adotar medidas para impulsionar ou incentivar os grandes e pequenos produtores a implementar FER, como por exemplo, eliminado impostos sobre o valor acrescentado, e investir no processo de crescimento e inovação tecnológica. De realçar que a transição energética não envolve apenas a adoção de FER, abrange também o nobre objetivo de proporcionar igualdade no acesso a fontes energia modernas e de prestar apoio às famílias vulneráveis, isto é, reduzindo a pobreza tradicional.

Abstract

The literature on the consequences of the transition on poverty in Southern African Development Community (SADC) countries is scarce. This paper aims to fill this gap by studying the consequences of the energy transition on energy poverty and traditional poverty. This research uses World Data Bank and World Health Organization databases to understand the consequences of the energy transition on traditional and energy poverty. An autoregressive distributed lag approach has been carried out to study 15 of the 16 SADC countries between 2000 and 2020. A battery of tests was carried out to assess the data's characteristics and the models' specifications. The tests pointed to the autoregressive distributed lag models estimated with the Driscoll and Kraay estimator as the most suitable one. The results of this dissertation indicate that the consumption of clean energy for cooking reduces energy poverty in SADC countries. Accordingly, this reveals the need for SADC member countries to have concrete public policies to provide their populations with better access to sustainable and modern energy sources. Thus, SADC member countries should consider investments in renewable energy sources, such as photovoltaic solar panels, contributing to increased access to electricity without further exacerbating traditional and energy poverty.

Keywords: Energy poverty, Energy transition, Southern African Development Community, Energy consumption for cooking, Electricity access.

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Acronyms List

ARDL	Autoregressive Distributed Lag
AU	African Union
CBN	Cost of basic needs
ECM	Error Correction Mechanism
EP	Energy Poverty
GHG	Greenhouse Gases
HDI	Human Development Index
IEA	International Energy Agency
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
MEPI	Multidimensional Index Poverty
NRE	Non-renewable energy sources
R&D	Research and development
RES	Renewable energy sources
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SDG	Sustainable Development Goal
SSA	Sub-Saharan Africa
TP	Traditional Poverty
VIF	Variance Inflation Factor
WAPP	West African Power Pool

1. Introduction

The process of transition from non-renewable energy sources (NRES) to renewable energy sources (RES) is being implemented around the world to protect the environment. All over the world, energy transition measures are being introduced to make energy systems less harmful to the environment. This implies that countries will have to move from an energy system whose production is mainly fueled by fossil sources to one that involves the integration of RES or clean energy sources (Macedo & Marques, 2023) . The energy transition and how it is being carried out is making families poorer, being this poverty is related to both energy and traditional poverty.

Energy poverty has become one of the most discussed issues in the Sub-Saharan African region (Acheampong, 2023; Garba & Bellingham, 2021; Sarkodie & Adams, 2020; Trotter, 2016) . According to the International Energy Agency (IEA), nearly 2.5 billion people worldwide rely on traditional biomass for cooking (IEA, 2021). Approximately 120 million use kerosene, and 170 million use coal. In Sub-Saharan Africa (SSA), approximately 905 million people lack access to clean energy for cooking (Birol, 2020). In addition, 578 million people do not have access to electricity (Birol, 2020). These findings highlight the high levels of energy poverty (i.e., lack of access to electricity and clean energy sources for cooking) in the Southern African Development Community (SADC). One of the most worrying cases of access to electricity in SADC is Malawi and the Democratic Republic of Congo, which have an electrification rate of 15% and 20%, respectively (World Bank, 2022).

According to a report by the World Bank Group (2022) , 60% of people in SSA live in extreme poverty - around 389 million people -more than in any other African region. The SSA region's poverty rate is about 35%, the world's highest. To achieve the first Sustainable Development Goal (SDG) of 2030 (eradicate extreme poverty), every country in the SADC region should reach 9% annual growth in Gross Domestic Product (GDP) *per capita* by the end of this decade. This is a significant hurdle for SSA, where per capita income growth was around 1.2% in the decade before COVID-19 (World Bank Group 2022).

The debate on energy poverty has expanded in the literature, although a universal definition of energy poverty has yet to be established (Bouzarovski, 2014; Pereira & Marques, 2023; Sovacool, 2015; Sy & Mokaddem, 2022) . It is argued that for developed countries, energy poverty manifests as a lack of monetary means to afford modern energy services (González-Eguino, 2015; Sy & Mokaddem, 2022) . Furthermore, it is essential to highlight that when referring to energy costs, energy poverty can also be interpreted as a lack of ability to consume modern and relatively more expensive energy resources (González-Eguino, 2015).

In developing countries, energy poverty manifests as a lack of access to electricity (Renewable Energy Agency, 2013) . This definition is also supported by the IEA, which defines energy poverty as a lack of access to clean fuels (such as electricity and natural gas) and cooking equipment, or a heavy reliance on traditional biomass energy for cooking meals (Birol, 2020.; Florini, 2011) . As all SADC countries are developing countries, this study follows the IEA and Renewable Energy Agency definitions. Lack of access to electricity means that people are deprived not only of basic services such as cooking and heating, but also of other fundamental factors to human development, such as access to education, health, information, and political participation (González-Eguino, 2015). This motivates this research to analyze how the transition to modern and clean energy sources can reduce energy poverty in the SADC.

Different perceptions of traditional poverty led to different definitions of the poverty concept, mainly due to its multidimensional nature. Even so, there is a common understanding among SADC member states. Poverty refers to a person or family not in a situation of well-being, defined as people with low or insufficient income to ensure adequate nutrition and with few material assets (SADC, 2020). The cause of traditional poverty is mainly described as a lack of income and resources to meet basic needs, such as food, shelter, clothing, and an acceptable level of health and education (Washington, 2001). As traditional poverty is a widespread phenomenon in the SADC region, this research will also focus its analysis on it.

This work intends to understand how access to electricity and energy transition in cooking (using clean energy forms for cooking) can reduce both traditional and energy poverty. Accordingly, it aims to disseminate empirical evidence on energy poverty in SADC countries, which is scarce, and to provide policy guidance on how to improve access to forms of clean energy. To do it, this study wants to address the following research questions: (i) does energy transition alleviate both energy and traditional poverty in SADC countries?; (ii) does access to electricity contribute to reducing traditional poverty in SADC?; and (iii) how do cooking energy consumption habits impact both energy and traditional poverty?

Existing studies have mainly examined the impact of governance, democracy, income inequality, and globalization on access to electricity (Acheampong, 2023; Acheampong et al., 2022; Sarkodie & Adams, 2020; Trotter, 2016). This study aims to fill this gap by studying the impact of clean energy consumption for cooking on both energy poverty and traditional poverty (income family, income inequality, extreme poverty) in the SADC. Therefore, this dissertation breaks new ground, providing a wider framework to design energy policies able to improve the socio-economic conditions of the most vulnerable.

This study analyses 15 of the 16 SADC countries using two indicators of energy poverty and traditional poverty. Data was obtained from the World Bank Indicator and the World Health Organization. An Autoregressive-Distributed Lag (ARDL) model was applied, using a panel data approach to answer the research questions raised. This method allows to observe the relationships established through the analysis of short-term dynamics and long-term adjustments. The results show that higher penetration of RES increases the consumption of clean energy for cooking. A substitution effect from fossil fuels to RES is noticeable in the overall electricity production. In fact, this research shows that in the long run, fossil energy consumption for cooking is replaced by clean energy sources for cooking. It is, therefore, crucial to develop concrete energy policies that incentivize the implementation of RES to ensure greater access to electricity in the SADC region, thereby reducing energy poverty and traditional poverty.

This dissertation is structured as follows: Section 2 presents the literature review on energy poverty, and Section 3 presents the status of the electricity system in the SADC region. Section 4 presents the data and the methodology used. The results are shown in Section 5 and discussed in Section 6. Lastly, Section 7 concludes and presents some policy implications.

2. Literature Review

Both energy and traditional poverty have received considerable attention in the literature (Pereira & Marques, 2023). The first concept of energy poverty was proposed by Lewis, who analyzed it from an economic perspective, stating that energy poverty was the inability of an individual or household to pay for energy. Besides, the author noted that inadequate energy consumption could affect people's standard of living (Lewis, 1982). Then Brenda Boardman (1991) defined households as energy-poor, those who spend 10% or more of their income on fuel or other energy services. Energy poverty has gained alternative labels with the increasing research in the field, such as fuel poverty, energy vulnerability, energy deprivation, energy precariousness, and energy overload (Fabbri & Gaspari, 2021) . The concepts of energy poverty differ between the global North and the global South. In the North, the concept is linked to fuel poverty, with more emphasis on Europe. While, in the South, the focus is on access to electricity and clean fuels for cooking, with more emphasis on African and Asian countries (Laldjebaev & Hussain, 2021).

In SSA, specifically in developing countries, the debate on energy poverty is based on the lack of access to electricity (Wang et al., 2023). For Bazilian et al., (2014) is a lack of access to affordable and quality energy services. Although the problem of energy poverty is conjectural at the level of countries in the SADC region, it should be noted that there is heterogeneity among them in terms of their electricity systems development (IRENA, 2020). Low access to electricity in SADC countries is increasing energy poverty, mainly for the vulnerable ones. This emphasizes the necessity to increase electrification, aiming to reduce household energy poverty rates (Monyei et al., 2022). This vulnerability of SADC countries is due to the lack of energy infrastructure to serve the population and the lack of income to pay for clean energy sources (Shihab et al., 2018).

The most widely used indicator to measure energy poverty in developing countries is the Multidimensional Index (MEPI) (Iddrisu & Bhattacharyya, 2015). This index was developed by (Nussbaumer et al., 2012) , who analyzed energy poverty regarding lack of access to modern energy services such as cooking, lighting, refrigeration, entertainment/education, and communication. Thomson et al., (2017) came to the same conclusion, stating that household energy poverty is a multidimensional phenomenon embodied in the lack of access to modern energy for cooking and heating.

SADC member states define poverty as the inability to consume enough food to keep the body alive or having food consumption below the defined poverty line (SADC, 2020). This means that households at the extreme poverty line are those whose income is close to the extreme poverty line. SADC Member States use absolute poverty to calculate poverty, except for Botswana and Mauritius, which use the concept of relative poverty. Botswana uses the poverty line of USD 1.90 to determine who is poor, while Mauritius uses 50 percent of the average monthly household income per adult equivalent to calculate the poverty line (Nkomo, 2007) . The remaining SADC member states use the cost of basic needs (CBN) approach to calculate the poverty line.

It should be noted that in the SADC region, income limits the free choice of household equipment and appliances and access to electricity. SADC member states use expenditure or income to measure inequality. They all calculate the Gini coefficient as a measure of inequality. The Gini coefficient measures the distribution of household income using the inequality index. The coefficient provides a numerical measure of the degree to which the Lorenz curve deviates from the income distribution line (SADC, 2020).

The energy transition involves concrete investments in the production of renewable energy sources, and it is specifically here that developing countries (SADC) encounter barriers to proceeding. It requires investments in research and development (R&D) (Chen et al., 2022), but these countries are not economically prepared to support it. Besides, energy poverty is necessarily a regional problem at the level of SADC countries. Regional cooperation should move beyond electricity trading to concrete interventions to reduce energy poverty, with policies focused on the local needs of each SADC member country.

There is a gap in the literature that consists of understanding how the energy transition can alleviate traditional and energy poverty in SADC countries. This research aims to fill this gap in the literature by studying how the energy transition, i.e., the electrification of economies and access to clean energy sources, impacts the traditional and energy poverty in the SADC.

3. Overview of the electricity system in the SADC region

The SADC has made significant progress in cooperation and integration since its inception in 1980. This progress has been achieved without neglecting its objectives of promoting sustainable and equitable economic growth and socio-economic development through efficient production systems. It is estimated that by 2023, SADC will comprise over 366 million people in 16 member states. SADC has evolved from a coordinating conference to an active regional development community, making it a key element in building African unity through the African Union (AU) (Monyei et al., 2018) . SADC has an average population growth rate of 3% per year, a GDP per capita of around US$6574, a Human Development Index (HDI) of 0.56, and an electricity access rate of 47% (SADC, 2020) . While these statistics are significantly higher than those of other SSA regions, they do not reflect the wide disparities in development that exist in the SADC region. The GDP per capita of the Pool member countries ranges from $390 (Malawi) to $8300 (Botswana), the HDI from 0.45 (Mozambique) to 0.73 (Malawi), and access to electricity from 18.02% (Malawi) to 91.23% (South Africa) (SADC, 2020).

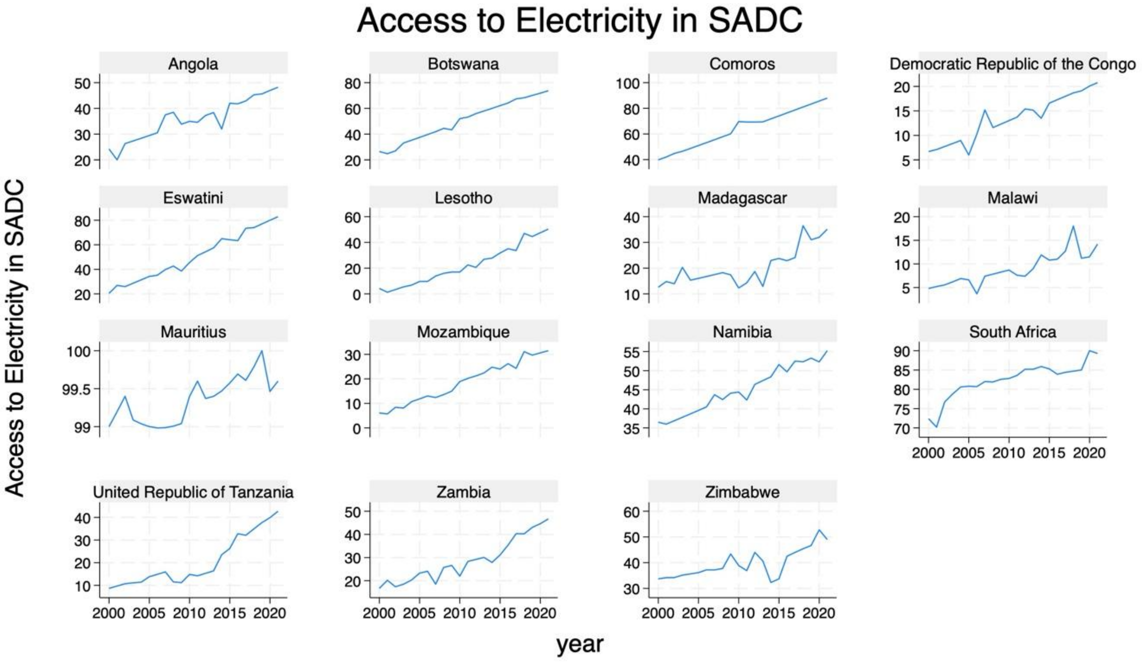

Fig. 1. Energy Poverty by Access to Electricity in SADC

The energy poverty in these countries is mainly related to the lack of infrastructure to meet energy needs. It should be made clear that most SADC Member States have developed national policies to ensure increased energy access at a national level, which include implementation targets. Typically, improved access is linked to the electrification rate - that is, the percentage of people able to access electricity through the main grid or mini-grids (Geoff Stiles & Charles Murove, 2018).

SADC still faces significant challenges in energy development and use. According to the 2019 Regional Master Plan for Infrastructure Development (RAPDRDI) Assessment Report, the following issues are highlighted: (i) only 32% of SADC rural areas in the region have access to electricity; and (ii) SADC has a lower electricity access rate than the African continent, (iii) approximately 50% of the region's residents have access electricity, while North African countries have 100% access to electricity; (iv) SADC electricity access deficit was expected to be addressed by 2019, but projects aimed at overcoming it are not meeting deadlines due to lack of financing; (v) slow migration to cost-reflective tariffs, poor project preparation, problems with Power Purchase Agreements, as well as lack of regulatory frameworks hamper investments and financing in the power sector; (vi) weak infrastructure and foreign commitments inhibit the utilization of the region's abundant oil and natural gas resources; and (vii) price and infrastructure barriers such as grid connections, manufacturing activity and quality testing hinder the development of the RES potential (SADC, 2020).

According to the IRENA (2013), and Southern African Power Pool (SAPP) report, the SADC had an installed generation capacity of 71.3 GW (0.2 kW per capita), reaching an operational production peak of about 59 GW - the highest of any power pool in SSA at the time. The current generation mix is dominated by coal-fired, hydro, and gas-fired power plants, which account for about 60%, 21% and 8% of total installed generation capacity, respectively. The region's installed wind and solar power capacity is less than 7% of the total generation capacity. Accordingly, the SADC electricity system is primarily based on fossil fuels, only subject to the seasonal volatility of hydropower generation.

Electricity demand in the SADC region is estimated at around 280 TWh (828 kWh per capita) - over 480% of the West African Power Pool (WAPP), which has about 1.3 times the population of SADC - and is projected to reach 461.2 TWh (65% increase) by 2025 (SAPP, 2019) . South Africa's national power utility, Eskom, accounts for about 51% of installed generation capacity in the SADC. Although fossil fuels and hydropower dominate the current electricity market in the SADC region, it is worth highlighting that there has been progress in integrating RES. In fact, wind and solar power account for about 26% and 12% of the region's electricity generation mix, respectively.

4. Data and Methodology

To answer the research questions raised in this research, a quantitative research design was conducted, with the main objective of assessing the impact of the energy transition on energy and traditional poverty. This dissertation studies energy poverty through the following indicators: access to electricity (*EP_ACCELE*), percentage of the population using clean energy for cooking (*EP_CLEAN*), and percentage of the population using fossil energy for cooking (*EP_FOSSIL*). Traditional poverty is analyzed through household income (*TP_INC*), Gini *per capita* (*TP_GINI*), and the employed population below the international poverty line over 15 years (*TP_POV15*). To clarify and distinguish between the energy poverty and traditional poverty indicators, the prefix '*EP_*' was added to the energy poverty indicators, and the prefix '*TP_*' was added to the traditional poverty indicators. The share of RES on electricity generation, the percentage of the population using biomass/wood, gas, coal, charcoal, kerosene, and electricity energy for cooking evaluated the impact of the energy transition on both energy and traditional poverty. The energy intensity, total natural resources rents, and gross domestic product *per capita* were used as control variables. Table 1 shows the variables used in this analysis, presenting their definitions, measurements, and sources.

Table 1. Variables definition

Variable	**Definition**	**Measure**	**Source**
EP_CLEAN	Share of population using clean energy for cooking	Percentage	WHO
EP_FOSSIL	Share of population using fossil energy for cooking	Percentage	WHO
EP_ACCELE	Electricity Access	Percentage	WHO
TP_INC	Household Income	$ constant 2015	WDB
TP_GINI	Gini	Index	WDB
TP_POV15	Employed population below international poverty line above 15 years	Percentage	WDB
GDPPC	Gross domestic product per capita	$ constant 2015	WDB
RESSHARE	Share Renewable Energy Sources	Percentage	WDB
EINTS	Energy Intensity	Index	WDB
RENTS	Total Natural Resources	Percentage	WDB
BIO/Wood	Biomass/wood use for cooking	Percentage	WHO
GAS	Gas use for cooking	Percentage	WHO
COAL	Coal use for cooking	Percentage	WHO
CHCOAL	Charcoal use for cooking	Percentage	WHO
KEROS	Kerosene use for cooking	Percentage	WHO
ELECT	Electricity use for cooking	percentage	WHO

Notes: WDB means World Data bank; and WHO means World Health Organisation

This study focuses on 15 of the 16 countries of the SADC region, namely Angola, Botswana, Comoros, Democratic Republic of Congo, Eswatini, Lesotho, Madagascar, Mauritius, Malawi, Mozambique, Namibia, South Africa, Tanzania, Zambia, and Zimbabwe. Seychelles was not included because the variables most relevant to this study, namely energy poverty and traditional poverty, did not contain data. The empirical analysis was carried out for the period of 2000 to 2020. Table 2 presents descriptive statistics. The variables used were converted to their natural logarithms. The prefix '*L*' represents the natural logarithms and the prefix '*D*' denotes the first differences of the natural logarithms.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
EP_CLEAN	315	29.90924	29.30994	.5	98.9
EP_FOSSIL	315	70.09076	29.30994	1.1	99.5
EP_ACCELE	315	39.30552	27.0847	1.3	100
TP_INC	315	2.38E+08	9.35E+08	901.6792	4.89E+09
TP_GINI	315	5082.921	4977.763	400	5260
TP_POV15	313	38.69958	26.89313	0.04	96.36
GDPPC	315	2437.111	2401.309	269.1096	10959.34
RESSHARE	315	59.08473	30.1753	0	98.34
EINTS	315	7.505683	4.799387	2.13	26.91
RENTS	315	8.280898	9.520214	0.0011721	55.87479
BIO/wood	315	10.7282	12.55031	0	52.3
GAS	315	1.090321	2.671134	0	15.43
COAL	315	0.0641952	0.2100361	0	1.55
CHCOAL	315	3.293854	5.556253	0	31.6
KEROS	315	0.4454857	1.328704	0	8.46
ELECT	315	3.150025	9.376529	0	47.98

Notes: Max. – Maximum; Min. – Minimum; Std. Dev. – Standard deviation; Obs – Observations.

The cross-sectional dependence (CD) test proposed by (Pesaran M. H., 2004) was applied once common shocks and spatial dependence between SADC countries were expected. The results of the CD test indicate the presence of cross-sectional dependence in all level variables and most first-difference variables (see Table 3). Consequently, the order of integration of the series was assessed using the second-generation unit root test, CIPS, proposed by (Pesaran, 2007). This test points out that the majority of the variables are I(1). However, there are variables that could be I (0) or borderline, i.e., I(1)/I(0) (see Table 3).

Table 3. Cross section dependence and unit roots tests

	CD test	**Unit Roots test (CIPS)**			
		Level		**First differences**	
		With Trend	**Without Trend**	**With Trend**	**Without Trend**
LEP_CLEAN	33.54***	5.102	3.261	3.45***	-5.842***
LE_PFOSSIL	1.02	0.637	6.881	-1.32	-5.219***
LTP_INC	15.07***	1.476	0.811	12.02***	-7.892***
LGDPPC	31.4***	1.655	-0.484	18.69***	-5.786***
LEP_ACCELE	29.18***	-5.104***	-7.027***	2.7***	-12.959***
LRESSHARE	46.21***	1.295	0.355	45.68***	-7.089***
LEINTS	17.44***	-0.446	-2.21*	0.77	-7.491***
LRENTS	7.62***	-0.368	-1.448*	7.52***	-8.075***
LTP_GINIPC	40.27***	2.493	0.694	11.47***	-5.181***
LBIO/wood	8.14***	3.448	1.446	0.59	-6.687***
LCOAL	N/S	5.224	6.888	N/S	-0.17***
LELECT	26.42***	3.81	2.288	1.16	-5.325***
LGAS	N/S	4.561	2.325	N/S	-5.835***
LKEROS	N/S	3.55	3.356	N/S	-4.612***
LCHCOAL	N/S	2.163	2.605	N/S	-4.542***
LTP_POV15	2.18**	-0.151	-3.138***	6.61***	-6.444***

Notes: *, **, *** denotes the statistical significance at the 10%, 5%, and 1% level, respectively. The null hypothesis of the CIPS test is the series integrated of order one, and the null hypothesis of the CD test is cross-sectional independence.

Two groups of models were carried out to analyze poverty (*traditional poverty models*) and energy poverty (*energy poverty models*). This choice was motivated by the energy transition to assess its impact on both energy and traditional poverty reduction. A preliminary analysis was made to check for possible collinearity and multicollinearity phenomena. Any doubts about collinearity and multicollinearity were set aside from the analysis of the correlation matrix (see Table A.1. in the Appendix) and variance inflation factors (VIF) statistics. A battery of model specification tests was also carried out (see Table 4). The specification tests performed were the Modified Wald test for heteroscedasticity (Rilstone, 2002) ; the Wooldridge test for serial correlation (Drukker, 2003); Pesaran (Pesaran M. H., 2004) , Frees (Frees, 1995) and Friedman's (Friedman, 1937) cross-sectional dependence tests; the Ramsey RESET (Ramsey, 1969) test to check omitted variable bias and the Hausman test, Fixed Effects (FE) vs. Random Effects (RE), which tests the presence of individual effects against random effects.

Table 4. Models specification tests

Models		RESET	Modified wald	Wooldrige	Pesaram	Frees	Friedman	Hausman
TRADITIONAL POVERTY	*TPGINI*	7.22***	403.5***	21***	2.403*	0.012*	29.438***	25.26**
	TPPOV15	62.85***	888.08***	43.006***	-1.411	1.241	13.709	133.34***
	TPINC	2.37*	623.47***	17.615***	1.926**	0.022	19.636	56.7***
ENERGY POVERTY	*EPCLEAN*	3.56**	9475.61***	0.425	-1.004	0.351	10.623	92.02***
	EPFOSSIL	66.96***	638.65***	2.257	1.248	0.063	20.234	131.29***
	EPACCELE	26.09***	1875.15***	17.635***	1.789*	0.191	12.464	50.13***

Notes: *, **, *** denotes the statistical significance at the 10%, 5%, and 1% level, respectively.

The Modified Wald test points to the presence of heteroscedasticity in all models. The Wooldridge test notes the presence of panel autocorrelation in all models. The Pesaran, Free's, and Friedman tests do not denote the presence of contemporaneous correlation, except for the *TPGINI model*. The Hausman test indicated the presence of fixed effects in all models.

An ARDL approach was applied once the variables under study were a mixture of stationary and non-stationary. The ARDL approach has the advantage of apportioning the total effects into short- and long-run effects (Pesaran et al., 2001). Besides, the ARDL model allows the treatment of endogeneity, analyses direct and indirect effects on elasticities, and provides an unbiased long-run estimate (Ahmad et al., 2017). As pointed out by the specification tests, the ARDL models were estimated by the Driscoll and Kraay (1998) estimator with fixed effects because it is suitable to deal with the data characteristics and model specifications.

5. Results

The results of *traditional poverty models* are presented in Table 5. The traditional poverty indicators highlight how energy transition impacts the Household Income, GINI *per capita*, and the employed population below the international poverty line over 15 years. The results of *energy poverty models* are shown in Table 6. The *energy poverty models* examine the impact of energy transition on electricity access, the use of clean energy sources for cooking, and the use of fossil energy for cooking. The high statistical significance of Error Correction Mechanisms (ECM) in all models. This emphasizes the appropriateness of the ARDL models to study the data of this research once models have a long memory.

As seen in Table 5, the ECMs of traditional poverty models show a slow return to equilibrium, with household income being corrected by 16% per year and the GINI by 22% per year. This demonstrates the slow ability of the household income and GINI to respond to potential economic and political shocks. In contrast, the employed population below the international poverty line over 15 years has a faster annual correction at 58% per year, which shows that it responds more quickly to an economic or political shock.

Table 5. Results of traditional poverty models

Measured by	**Family Income**	**Extreme poverty**	**GINI (income inequality)**
Short-term variables			
DLTPINC		-0.4479***	0.2158***
DLGDPPC			0.8627***
DLEP_ACCELE		-0.2133***	
DLRESSHARE	0.0182***	-0.0116***	
DLEINTS	-0.4326***		-0.1297*
DLRENTS	-0.0360***		
DLCOAL	0.4330***	1.4182**	
DLELECT		-0.1956*	-0.0625***
DLKEROS		1.0018*	
DLCHCOAL	1.0682***	3.0210***	1.1103***
DLTP_POV15	-0.0945***		
ECM	-0.1692***	-0.5788***	-0.2171***
Long-term variables			
LEP_CLEAN(-1)			0.0544***
LTP_INC(-1)		-0.2734***	0.0544***
LGDPPC(-1)			0.1713***
LACCELE(-1)		-0.1799***	
LRESSHARE(-1)	0.1061***	-0.3138**	-0.0966*
LBIO/wood(-1)	0.1498***	1.4661***	
LCOAL(-1)		-0.2902***	-0.1298**
LELECT(-1)	-0.0406	-0.3914***	
LGAS(-1)			0.0937**
LKEROS(-1)		-0.4398***	0.0894**
LCHCOAL(-1)	-0.0468		
Constant	1.2477***	1.6524***	0.3131

Notes: *, **, *** denotes the statistical significance at the 10%, 5%, and 1% level, respectively.

The results of Table 5 show that, in the short run, an increase of 1 percentual point (pp) in *LRESHARHE* provokes a drop of 0.0116 pp in the number of households suffering from energy poverty. In the long term, a 1% increase in electricity consumption for cooking reduces the number of households suffering from extreme poverty by 39.14% (see Table 5, *extreme poverty model* results). In the *extreme poverty model*, in the short run, a 1 pp increase in coal and kerosene consumption for cooking causes a rise in the traditional poverty of around 1.4182 pp and 1.0018 pp, respectively. Therefore, the SADC countries could effectively reduce the traditional poverty with the energy transition. In other words, they could reduce traditional poverty by substituting fossil fuels with RES.

Table 5 shows that the share of RES in the electricity mix reduces traditional poverty by (a) increasing the household income, (b) reducing the number of households suffering from extreme poverty, and (c) reducing the economic inequalities, i.e., the GINI coefficient. This implies that policymakers need to pay attention to RES, for instance, by subsidizing the installation of solar photovoltaic panels or seeking sources for funding the implementation of RES. Besides, as the electricity consumption for cooking also reduces economic inequalities and the number of households in extreme poverty, electrification should also be pursued.

Table 6. Results of energy poverty models

Measured by	Access electricity	Clean energy	Pollutant energy
Short-term variables			
DLTP_INC			-0.0321**
DLRESSHARE	-0.0117***		-0.0020***
DLEINTS	-0.3296*	0.0139**	
DLBIO/WOOD	0.2719*	1.7628***	2.8165***
DLCOAL	-2.7669*	0.8842***	0.0719**
DLELECT	-0.8245*		
DLGAS			0.1355***
DLKEROS		-0.7218**	0.7150***
DLTP_POV15	-0.3640***		
ECM	-0.4224***	-0.0371***	-0.0983***
Long-term variables			
LTP_INC(-1)		0.0227***	
LRESSHARE(-1)		0.0600***	-0.0283**
LEINTS(-1)	-0.2580*	0.0639**	
LRENTS(-1)		0.0128**	
LTP_GINIPC(-1)		0.0257*	
LBIO/WOOD(-1)	0.6269***	-0.0471*	0.1415***
LCOAL(-1)	0.6458**		
LELECT(-1)	0.3561***		-0.0314***
LGAS(-1)		0.1106***	
LKEROS(-1)	-0.4043**	0.0637***	0.0564***
LCHCOAL(-1)			0.0162**
LTP_POV15(-1)	-0.1199***		
Constant	1.1279***	-0.4938***	0.6435***

Notes: *, **, *** denotes the statistical significance at the 10%, 5%, and 1% level, respectively.

In the energy poverty models, the ECMs show that access to electricity have a slightly balanced adjustment, standing at 42% per cent per year (see Table 6). This shows its capacity to respond to economic and political shocks that may occur. In contrast, *Clean energy* and *Pollutant energy models* have a slow adjustment speed towards equilibrium, only 3% and 9% per year, respectively. These results shows that the households' energy consumption mix for cooking is not easily adjustable.

In the short term, a 1 pp increase in the biomass/wood and coal consumption for cooking incentivizes the electricity access by 0.2719 pp and 2.7669 pp, respectively. In the long term, a 1% increase in biomass/wood and coal consumption for cooking rises the electricity access by 62.69% and 64.58%. Furthermore, in the long run, both natural gas and kerosene consumption for cooking incentivizes households for the consumption of clean energy for cooking (see Table 6, *clean energy model* results).

In both short- and long run, it could be seen that the share of RES in the electricity mix and the electricity consumption for cooking reduces the consumption of fossil fuels for cooking purposes (see Table 6, *Pollutant energy model* results). These results denote of the potential participation of the households on the energy transition, by changing their cooking habits. Therefore, it is worth pointing out that the share of RES in the electricity mix, electricity and natural gas consumption for cooking could represent the turning point from fossil fuels consumption to the consumption of cleaner energies. In other words, their use means the energy transition is taking place.

6. Discussion

In the SADC region energy transition process is the need to achieve target 7.1 of the Sustainable Development Goals (SDGs), adopted by the United Nations in 2015. This SDG calls for universal access to electricity and clean cooking technologies and fuels by 2030. At a country level, in the SADC region, access to electricity has progressed faster than access to energy for cooking. This is evidenced by the fact that in 2019, 759 million people in the world still did not have access to electricity, with 570 million people coming from SSA. In terms of clean energy for cooking, the picture is even worse in SSA: 84% of the population, i.e., 894 million people, do not have access to clean energy for cooking. Therefore, this dissertation study of the consequences of the energy transition on both traditional and energy poverty is highly relevant having also important political implications.

As of 2020, the SADC region has reported a mere 32% of rural areas having access to electricity, while only 50% of the overall population in the region enjoys the same privilege (Birol, 2020). Besides, in this region, approximately 905 million people do not have access to clean energy for cooking (Birol, 2020). Households have often resorted to paraffin and charcoal to satisfy their cooking needs. This disparity highlights the need for more efforts to be made towards improving access to electricity in the region, particularly in remote rural areas. Therefore, this research aims to contribute to the energy transition policies design, providing a comprehensive understanding of the impact of the energy transition on both energy and traditional poverty.

This dissertation' empirical results show us that despite the abundant resources available in the SADC region, this region of the world is also, paradoxically, the least developed in the energy transition. In fact, this region has higher levels of energy poverty (i.e., lack of access to electricity and modern energy forms), and a high propensity to use fossil fuels for cooking. It should be stressed that this research results are in line with the Literature (e.g., Ongo Nkoa et al., 2023). The SADC region experiences a significant poverty rate, which is closely tied to the prevalent use of fossil fuels as a source of cooking fuel. This reliance on non-RES has contributed to the region's energy poverty, which is a pressing challenge that requires urgent attention and innovative solutions.

The results of this dissertation disclose that RES contribution to the electricity generation mix reduces both energy and traditional poverty. This reduction in energy poverty could result from the RES's decentralized potential, mainly solar photovoltaic and wind power. As the SADC region has a high potential to generate electricity from solar photovoltaic panels, it is crucial for these countries to implement it. On the one hand, the solar photovoltaic implementation could enable a rise in electricity access in remote locations (if linked to local or micro-grids). On the other hand, this RES technology could reduce the electricity price, once sun is an abundant endogenous resource in the SADC region. Therefore, solar photovoltaic implementation could enable households to use clean energy for cooking through off-grid access to electricity, job creation (which increases their income and purchasing power), and lower electricity prices (which increases their purchasing power).

The IEA report (IEA, 2022) warns of the great danger that biomass/wood and coal/charcoal are causing to the health of families, even leading to the death of children and adults. Coal is one of the energy sources that produces the highest levels of greenhouse gas emissions, provoking also higher levels of indoor pollution (Chandran Govindaraju & Tang, 2013). This research shows that consuming biomass/wood, coal, and charcoal for cooking reduces traditional poverty. This occurs because these energy forms are available at low prices and are often used by vulnerable households. Notwithstanding, *Energy poverty models* reveal that biomass/wood, coal, and charcoal incentivize the consumption of clean energy forms for cooking and also access to electricity. Consequently, the electrification of the SADC region is of utmost importance. This will incentivize households to consume electricity instead of other cheaper but pollutant energy forms.

As this research stresses, the energy transition in SADC to modern and clean energy forms can reduce both energy and traditional poverty. However, SADC countries lack access to electricity, i.e., electrification, which is one obstacle to the energy transition. Another obstacle is the difficulty of obtaining funding for the deployment of RES once the SADC countries have budget difficulties in meeting their expenses. One measure that policymakers could adopt to boost or incentivize large and small producers to implement RES could be the removal of value-added taxes, easing the financial burden of the economic agents. It is also essential to invest in the process of growth and innovation. Accordingly, SADC countries should follow the path taken by Developed countries, such as the European ones, in the search for know-how.

In sum, energy policies in the SADC region must evolve to reduce energy poverty among the most vulnerable households, without hampering traditional poverty (which already experiences higher levels in this region). Therefore, SADC countries' governments must develop projects to increase energy literacy, informing society about the harmful impacts of fossil fuels on the environment and indoor pollution, and the benefits of electricity consumption generated by RES. Develop policies that encourage foreign direct investment, allowing for investments in RES and the expansion of electrical grids. The installation of a distributed generation gird (local or micro-grids), which are crucial to provide electricity access in remote areas. Lastly, governments should also provide subsidies for off-grid system installation, particularly in rural areas where financial constraints are common. The journey towards an energy transition is not merely about adopting alternative sources. It also encompasses the noble aim of providing equal access to modern energy and rendering support to those in need.

7. Conclusion

This research focuses on understanding the impact of the energy transition on energy and traditional poverty in 15 of the 16 SADC countries. This work used the World Data Bank and World Health Organisation databases, studying the period from 2000 to 2020. A battery of tests was carried out to assess the characteristics of the data and the specifications of the *energy poverty* and *traditional poverty models*. The tests pointed the ARDL estimated with the Driscoll and Kraay estimator as the most suitable one. Furthermore, the ARDL reveals the short- and long-run effects, which provides relevant information for making concrete decisions to help the SADC improve its energy transition, not harming vulnerable households.

The results of this research confirms that the RES deployment reduces both traditional and energy poverty. Therefore, investment in RES, such as solar photovoltaic and wind power, and its installation in local or micro grids, are crucial for increase the electricity access (reducing energy poverty). Besides, as the sun is an abundant resource in SADC region, and could also reduce the electricity prices, increasing the access to modern and clean energy sources in this region. This means that the energy transition could be developed and implemented without further exacerbating both energy and traditional poverty.

This dissertation also reveals that the consumption of fossil fuels such as charcoal and biomass/wood (the most widely used energy sources in the SADC region) contributes to reducing traditional and energy poverty among households. However, it is worth emphasizing that these fuels result in indoor pollution, which has also been noted as one of the biggest causes of death among children and adults in this region. This reality also denotes the urgent need for SADC member countries to adopt concrete and focused public policies to provide their populations with better access to sustainable and modern energy sources, mainly for cooking purposes.

To mitigate the impact of the energy transition on poverty, SADC member countries should use some of their budget surpluses to invest in RES or incentivize foreign direct investment. Besides, SADC countries can provide tax incentives (removal of value-added taxes on the import of solar photovoltaic panels) for small (individuals) and large producers (companies) and increase taxes on pollution. For future research, it would be interesting to carry out an individual study of each SADC country to better understand the impact of the energy transition on both traditional and energy poverty. Furthermore, this analysis could also be performed in urban areas (urban, and rural) to disclose the disparities between these areas. Future research should focus on energy policies to increase the access to electricity, reducing the energy and traditional poverty for the most vulnerable. This means, policies to promote a just energy transition for all.

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Table A1. Correlation matrix

Variable	*EPCLEAN*	*FOSSIL*	*ACCELE*	*INC*	*GINI*	*POV15*	*GDPPC*	*RESSHARE*	*EINTS*	*RENTS*	*BIO*	*GAS*	*COAL*	*CHCOAL*	*KEROS*	*ELECT*
EPCLEAN	1															
FOSSIL	-0.0243	1														
ACCELE	0.3941	-0.462	1													
INC	-0.096	-0.199	0.1345	1												
GINI	0.368	-0.457	0.7956	0.1116	1											
POV15	-0.2927	0.6832	-0.8192	-0.096	-0.72	1										
GDPPC	0.3683	-0.465	0.8119	0.0916	0.989	-0.7482	1									
RESSHARE	-0.4075	0.5229	-0.7154	0.0514	-0.78	0.7215	-0.782	1								
EINTS	0.0164	0.5274	-0.4749	-0.123	-0.5	0.5529	-0.493	0.4799	1							
RENTS	0.0815	0.4047	-0.3605	-0.138	-0.31	0.3773	-0.304	0.3315	0.2086	1						
BIO	-0.0684	0.9923	-0.506	-0.205	-0.5	0.7214	-0.508	0.568	0.5573	0.383	1					
GAS	0.3127	-0.036	0.0934	-0.092	0.164	-0.1186	0.1591	-0.1864	-0.272	0.571	-0.07	1				
COAL	0.6624	0.0739	0.2669	-0.07	0.19	-0.1268	0.2118	-0.2967	0.1499	-0.05	0.034	0.014	1			
CHCOAL	-0.1166	0.9002	-0.4138	-0.153	-0.4	0.6097	-0.409	0.422	0.4142	0.446	0.87	0.011	-0.07	1		
KEROS	0.758	0.0741	0.3059	-0.078	0.251	-0.2044	0.2704	-0.3216	0.0839	-0.09	0.025	0.059	0.91	-0.07	1	
ELECT	0.9615	-0.025	0.3907	-0.073	0.343	-0.2783	0.3451	-0.3786	0.0922	-0.08	-0.06	0.04	0.69	-0.13	0.8	1

Appendix