Incorporating Resilience and Sustainability in Renewable Energy Development: A Cameroon Case Study

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Abstract

There are two twin and perhaps conflicting challenges that face sustainable energy development which are increasing modern energy access to the energy poor while decarbonizing the energy system in order to mitigate climate change. Electricity is a modern source of energy that is absent in many parts of the world, especially in Sub-Saharan Africa where more than two thirds of the population are living without electricity. Cameroon which is the focus of this case study also has a low electricity access rate; 56.8% of its total population according to World Bank statistics. To mitigate this energy poverty approximately 70% of Cameroonians continue to use traditional biofuel energy for cooking, heating, and lighting such as fuelwood and coal. Biofuels are a type of renewable energy (RE) however, traditional energy use has detrimental health and environmental consequences especially in face of climate change, which creates questions on their continued sustainability. Furthermore, although Cameroon is rich in other renewable energy resources such as hydro energy and holds unharnessed solar potential, the country has failed to increase modern energy access to its population. These problems with RE development in Cameroon highlight that more concern should be accorded to sustainable energy development in order to maximize the benefits and decrease the environmental and social costs of energy development from both conventional (oil and gas) as well as renewable energy sources. Targeting this statement, this paper will use secondary sources to outline the problems with renewable energy development in Cameroon. Then, a theoretical framework that integrates three different bodies of thought; socio-technical, socio-ecology, and political ecology will be utilized to determine the main factors causing unsustainable energy development in Cameroon. Informing the discourse around the barriers of sustainable energy development will allow policy makers as well as practitioners to better plan for future RE projects, and will increase understanding of the need for future research to theorize ways in which renewable energy development can further resilient and just solutions for sustainable development.

Résumé

Le développement énergétique durable doit faire face à deux défis conjoints et peut-être contradictoires: accroître l'accès moderne des pauvres à l'énergie tout en décarbonisant le système énergétique afin d'atténuer les effets du changement climatique. L'électricité est une source d'énergie moderne qui est absente dans de nombreuses régions du monde, notamment en Afrique subsaharienne, où plus des deux tiers de la population vit sans électricité. Selon les statistiques de la Banque mondiale, le Cameroun, pays sélectionné pour cette étude, affiche également un taux d'accès à l'électricité faible ; 56,8% pour l'ensemble de sa population. Afin d'atténuer cette pauvreté énergétique, environ 70% des Camerounais continuent à utiliser l'énergie des biocarburants traditionnels pour la cuisson, le chauffage et l'éclairage, tels que le bois de feu et le charbon. Les biocarburants sont un type d'énergie renouvelable. Toutefois, l'utilisation traditionnelle de l'énergie a des conséquences néfastes pour la santé et l'environnement, en particulier face au changement climatique, ce qui soulève des questions sur leur durabilité. En outre, bien que le Cameroun soit riche en ressources énergétiques renouvelables telles que l'énergie hydroélectrique et qu'il détient un potentiel solaire inexploité, le pays n'a pas réussi à accroître l'accès moderne de l'énergie à sa population. Ces problèmes de développement de l'énergie renouvelable au Cameroun soulignent que le développement énergétique durable devrait faire l'objet d'une plus grande attention, afin de maximiser les avantages et de réduire les coûts environnementaux et sociaux du développement énergétique, tant par les sources d'énergie classiques (pétrole et gaz) que par les énergies renouvelables. Cela dit, ce document utilisera des sources secondaires pour décrire les problèmes liés au développement des énergies renouvelables au Cameroun. Ensuite, un cadre théorique qui intègre trois systèmes différents; sociotechnique, socio-écologique et écologie politique seront utilisés pour déterminer les principaux facteurs responsables du développement énergétique non durable au Cameroun. Le fait de lancer le débat sur les obstacles au développement des énergies durables permettra aux décideurs politiques et aux praticiens de mieux planifier leurs futurs projets d'énergies renouvelables et permettra de mieux comprendre la nécessité des recherches futures pour théoriser des façons par lesquelles le développement des énergies renouvelables peut apporter des solutions résilientes et justes au développement durable.

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List of Abbreviations

General Terms

EIA–Environmental Impact Assessment
EU–European Union
FAO–Food Agricultural Organization of the United Nations
HDI – Human Development Index
HIV AIDS human immunodeficiency virus
IAP– Indoor air pollution
IEA – International Energy Association
IT – Information Technology
LTK – Local Traditional Knowledge
MDGs– Millennium Development Goals
NIMBYISM – Not in my backyard syndrome
NGO – Non-governmental Organisation
OECD – Organization for Economic Cooperation and Development
PPP – Purchasing Power Parity
RE – Renewable energy
SDGs – Sustainable Development Goals
SME– Small-Medium Enterprises
UN – United Nations
UNDP – United Nations Development Program
UNFCC – United Nations Framework Convention on Climate Change
USEIA– United States Energy Information Administration
UPE – Urban Political Ecology
WHO–World Health Organization

Organizations in Cameroon
ARSEL– L'Agence de regulation du secteur de l'èlecticité
AER– l'Agence d'électification rurale
CSPH– Caisse de stabilisation des prixs hydrocarbures
EDC– Electricity Development Corporation
MINEE– Ministère de L'Energie et de L'Eau
MINEFOP– Ministère de l'Emploi et de la Formation professionnelle
GTNM– Groupe de Travail National Multisectoral
SCDP– Société camerounaise des dépôts pétroliers
SG – SOC Sithe Global Sustainable Oils Cameroon
SOCAPALM – Société des Palmeraies du Cameroun
SONARA– Socièté national de raffinage national
SONEL – Société Nationale d'Electricité du Cameroun

SNH– Société nationale des hydrocarbures

Cameroon's Electrical Network
EIG–Eastern Isolated Grid
NIG–Northern Interconnected Grid
SIG–Southern Interconnected Grid

Cameroon Government Official Plans
DSRP–Document de stratègie de reduction de la pauvretè
ESDP– Energy Sector Development Plan
ESMAP–Energy Sector Management Assistance Program
GESP– Growth and Employment Strategy Paper
NEAPRP– National Energy Action Plan for Poverty Reduction
REMP– Rural Electrification Master Plan

Empirical Measurements
kW–Kilowatt
GW– Gigawatt
GHI– Global Horizontal Irradiance
kWh– Kilowatt hour
Ktoes–Kilotonne of oil equivalent
Mha– Million hectares
Mt– Million tons
Mtoe–Million tons of oil equivalent
MW– Megawatt
TCF– Trillion cubic feet
TFC– Total Final Consumption
TPES – Total Primary Energy Supply
TW– Terawatt
TWh– Tera watt hour
W–Watt

Chapter 1

Introduction

1.1 Context

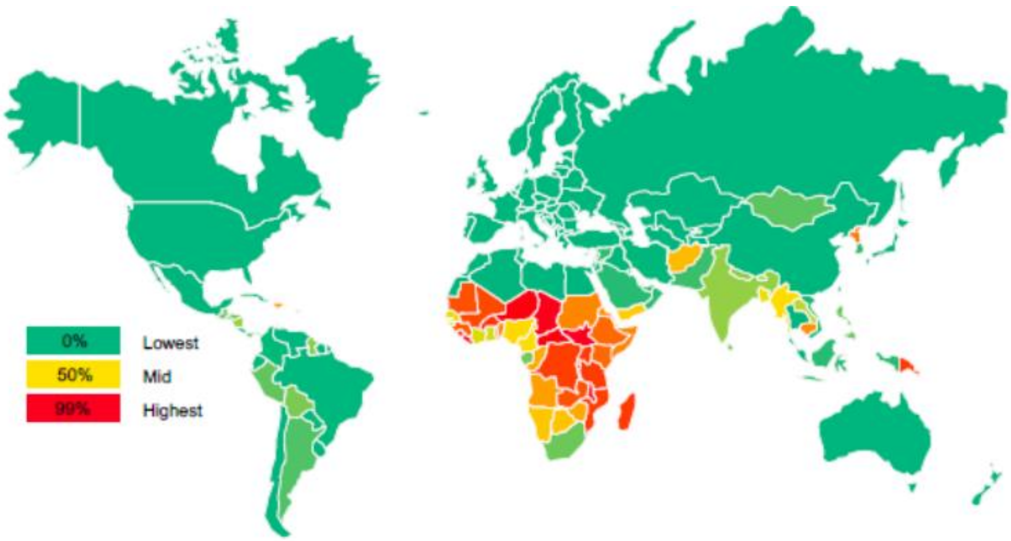
Sustainable energy has become a key component of international development. Current initiatives include the RIO+20 paragraphs 125-129 that highlight the role of energy in the struggle to combat poverty and Sustainable Development Goal (SDG) 7[1], which aims to ensure access to “affordable, reliable, sustainable, and modern energy for all” (UN, 2015). Sustainable energy therefore is confirmed as a fundamental human need. However, the United Nations (UN) failed to define what comprises sustainable energy as well as other key terms such as “modern” and “access” thereby weakening the ability of the SDGs to keep politicians accountable to the global goals (Calzadilla & Mauger, 2018). There are no universally agreed definitions of sustainable energy, however by using the rationale of the internationally recognized Brundtland Report, one can define sustainable energy as energy that meets the current needs of the population while not inhibiting the ability of future generations to meet their energy needs (Brundtland Commission, 1987). Access to energy such as electricity remains unequal with the region of Africa, specifically Sub-Saharan Africa at electricity levels far lower than industrialised nations (Figure 1.1). Therefore, the first component of sustainable energy; meeting current energy needs, is not being met. In addition to the energy access challenge another key barrier to sustainable energy development is that conventional forms of energy from the burning of fossil fuels[2] has caused anthropogenic climate change to occur according to international organizations such as the United Nations Framework Convention on Climate Change (UNFCCC, 2001). Furthermore, if developing countries mirror the energy processes of developed nations than green-house gases will rise, further exacerbating climate change (Organization for Economic Cooperation and Development (OECD), 2012). On the other hand, developing countries often point to the importance of energy for development in order to

[1] RIO+20 is a UN Conference on Sustainable Development that occurred in Rio de Janeiro, Brazil in 2012 which resulted in a policy document that replaced the Millennium Development Goals (MDGs) with the SDGs. The SDGs are global developmental goals aimed for the period of 2014-2024. SDG 7 is just one of the 17 goals.

[2] Fossil fuels are prehistoric remains of organic matter that have been converted by geological processes after many millennia into oil, gas, or coal. Burning fossil fuels generates electricity, however carbon-emissions are also released which causes harmful air pollution and also contributes to the green-house effect by trapping heat in the atmosphere which increases global temperature and the magnitude and prevalence of climatic weather events.

support economic growth and reduce poverty. The twin challenges of increasing energy access while decreasing carbon emissions globally could be seen as conflicting. A solution to this problem was proposed in the Kyoto Protocol[3] signed in 1997 which aimed to put limits on carbon emissions in the atmosphere. The agreement also included funding to developing countries in order to cut the costs associated with transitioning to cleaner energy technologies while also pursuing economic development under the Clean Development Mechanism (UNFCCC, 2001).

Figure 1.1: Share of Population Without Access to Electrical Grid (percent of total) in 2012



Source: Bloomberg New Energy Report, 2016

The renewable energy transition offers a way to increase energy access to developing countries while decreasing carbon emissions in developed countries because renewable energy (RE) results in less carbon in the atmosphere and can renew itself over time. Examples of RE include solar, wind, tidal, as well as geothermal energy that come from the earth's key mechanisms. The term renewable energy is sometimes used simultaneously with green, sustainable, or clean energy mistakenly because not all RE is inherently sustainable or clean, meaning without green-house gas emissions. For example, biofuels unleash carbon dioxide into the atmosphere and some critics argue that they also constitute as an inefficient use of land by increasing pressure on food security (Steer & Hanson, 2015). Other forms of RE such as solar energy requires the mining of materials

[3] The Kyoto Protocol is an internationally recognized treaty which committed the parties (nations) who signed to reduce greenhouse gas emissions in order mitigate climate change.

to make solar batteries and hydroelectricity projects causes environmental degradation, loss of wildlife habitat, and may threaten livelihoods and homes of people living on the land (Farfan, Peltoniemi, Breyer, 2018).

Cameroon the country selected for this research is located in Sub-Saharan Africa and has vast renewable energy potential according to many studies (Mboumboue & Njomo, 2016; Wirba *et al.*, 2015; Abanda, 2012). However, only 60% of the population have access to electricity which is unevenly distributed with 21% of the rural population connected to an electrical grid (IEA, 2017). The International Energy Association's (IEA) definition of an individual in "electricity poverty" when not having access to at least 120 kWh of electricity per year for lighting and other basic households needs (Monforti *et al.*, 2011). As a high proportion of Cameroon's population lack access to electricity, energy poverty is therefore a barrier for Cameroon's sustainable energy development which hinders its developmental goals as a whole (Wandji, 2013). In response to a lack of access to modern energy[4], traditional energy such as fuelwood, coal, and dung are used for cooking and heating. According to the United Nations Development Program (UNDP), 2.9 billion people still rely on traditional biomass sources and their continued use has important social consequences that effect development indicators such as health, gender equality, as well as ecological ramifications of continued deforestation (UNDP, 2016). Determining ways to respond to the twin challenges of increasing modern energy access while decarbonizing energy development processes are essential components of sustainable energy development.

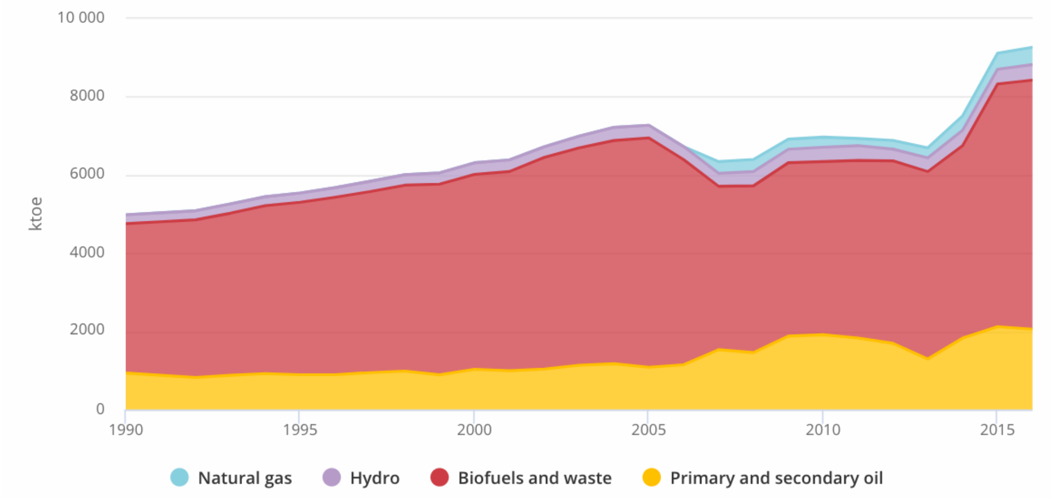
1.2 Statement of Problems

Traditional energy is still prevalent in Cameroon which could be explained by the unaffordability and unreliability of electricity and other alternatives and because traditional methods maintain strong cultural connotations especially in cooking methods and preferred food taste (Ouedraogo, 2013). Cameroon's Total Primary Energy Supply (TPES) is predominantly derived from biofuels

[4] Modern energy has no universal definition. However, the IEA, Word Bank, and UN define modern energy as having access to 500 kwh per household per year. Compared to developed countries this is very limited. Modern energy can also be looked at in terms of services; such as electrical or gas cooking, time saving appliances, and access to the internet as well as communication devices.

and waste where in 2016 it was at the highest levels at 6373 ktoe (Figure 1.2). When compared with the TPES of all sources which is 9,267 ktoe[5], the part of biofuels is 69% of Cameroon's total energy supply (IEA, 2016). Traditional energy causes environmental problems from the over-use of fuelwood as deforestation decreases the ability of forests to act as carbon sinks resulting in more carbon dioxide in the atmosphere. In Cameroon the demand for forest resources puts stress on the important forest of the Congo Basin which acts as one of the "lungs of Africa (Greenpeace International, 2017)".

Figure 1.2: Cameroon's Total Primary Energy Supply by Source from 1990-2016



Source: IEA, 2016

Traditional energy also seems to have a strong gender dimension where domestic tasks such as cooking are given to women. Indoor air pollution (IAP) generated from the prolonged burning of fuelwood causes respiratory problems, especially to women and children (Sulaiman *et al.*, 2017; Williams, Northcross, Graham, 2015). Carrying heavy loads of fuelwood over time can also cause injury such as back problems. This combined with IAP limits opportunities for education as illness or time spent finding fuelwood can affect women's ability to attend school or alternatively spend time on income generating activities (Sovacool, 2012). Health facilities also lack access to electricity which further exacerbates human developmental factors such as maternal health and infant mortality. Cameroon's Human Development Index[6] (HDI) is 0.56 ranked 151 out of 189

[5] Ktoe is a measurement of energy and is defined as the amount of energy released from burning a tonne of crude oil.
[6] The Human Development Index is a measure of human development formulated by the UNDP that takes into consideration a broader range of data in order to track changes over time than traditional GDP economic growth.

countries in 2018. The maternal mortality ratio (deaths per 100,000 live births) is 596 and infant mortality rate per 1,000 live births is 52.8% (UNDP, 2018). Improved electricity access has the potential to improve these indicators. Being energy poor can also be detrimental to Cameroon's development and its citizen's quality of life. Frequent electricity blackouts are harmful for business as the development of information technology (IT) requires electricity to run computers and communication services such as cellphones (Dominguez-Torres & Foster, 2011).

Historically, renewable energy development in Cameroon seems to have been tied to violent events. Hydroelectricity is controlled by one foreign-owned corporation currently called Eneo but its previous name AES-SONEL has much controversy around it, including two separate events in 2007 where students were killed for protesting the lack of electricity in universities (Musa, 2007). There is also evidence to support that the development of hydro-power dams has resulted in the relocation of communities vastly changing livelihoods strategies (International Rivers, 2005). Additionally, while traditional biomass is collected by people in the form of fuelwood or plant and animal matter, biofuels are processed biomatter usually ethanal based oils taken from palm trees and crops such as maize and canola. In the last few years, foreign-owned companies such as Sithe Global Sustainable Oils Cameroon (SG-SOC) and Société des Palmeraies du Cameroun (SOCAPALM) have been also cited in injustices such as land grabbing[7] and even alleged abuse and rape of women in nearby villages by security guards hired to protect palm plantations from theft (Etonde, 2018; Ndi, 2017). The above problems highlight that more attention should be given to sustainable energy development in Cameroon to determine if social, economic, and ecological systems are being affected negatively by current renewable energy projects and development.

1.3 <u>Research Objectives</u>

The proposed research seeks to understand the reasons why renewable energy development has been ineffective in increasing access levels to modern, reliable, and safe energy in Cameroon. To accomplish this an analysis of Cameroon's renewable energy system will be undertaken to assess

[7] Land grabbing is a practice of large-scale land acquisitions usually carried out by government bodies or foreign-owned companies that fail to consult with local communities that live on the land and/or provide fair compensation. Power differentials affect the legality of the practice where poorer communities are often the victims.

its implications on a social, economic, and ecological level. By bringing attention to the barriers that hinder sustainable energy development, new frameworks can emerge to inform future energy systems that are more equitable, efficient, and resilient.

- ◊ Describe the process of renewable energy development in Cameroon;
- ◊ Identify the problems associated with renewable energy development and its implications on the society, economy, and environment; and
- ◊ Offer recommendations and solutions to better achieve sustainable energy development.

1.4 Scope of the Study

This study aims to highlight the problems with renewable energy development in Cameroon by analyzing the process of its implementation from the early 1950s to present day. Factors that are inhibiting sustainable energy development will be outlined on a social, economic and environmental level and explained using a theoretical framework.

1.5 Limitations and Significance

This case study on renewable energy development in Cameroon is large in scope and includes multiple sectors of renewable energy such as hydropower and biomass which are vastly different with unique problems and barriers associated with their development. A clear understanding of the policies and actors involved in these sectors and relations between them is a significant undertaking. Obtaining current and reliable information on these sectors is an important limitation to consider.

This research seeks to further the understanding of the barriers of sustainable energy development in Cameroon. There are few studies on renewable energy development in Cameroon and explanations on why electricity access levels are not improving. Furthermore, renewable energy projects have often been cited as “good for the environment and development” at face value with limited research on the negative effects that renewable energy development has on the local population in Cameroon. A comprehensive study on the consequences of renewable energy development in Cameroon and an attempt to understand the reasons behind these problems using a three-pronged theoretical approach of socio-technical, socio-ecological, and political ecology frameworks has never been performed before to the researcher's knowledge. It is the hope that this paper will contribute to understanding the barriers of sustainable energy development and inform renewable development policies to better promote more resilient and sustainable practises in developing countries such as Cameroon.

1.6 Structure of the Research Paper

This paper will be divided into four chapters; The first includes the research framework and methodology to describe how the study will be conducted as well as the formation of the research questions. The second will outline the contexts and challenges of renewable energy development in Cameroon on a historical and political level in order to better understand the barriers that could be inhibiting sustainable RE development and causing problems. The third chapter is divided into two sections. The first section will comprise a data analysis of the consequences of renewable energy development in Cameroon on a social, environmental, and economic basis. The second section will offer theoretical explanations for the factors that could be contributing to ineffective renewable energy development in Cameroon. The last chapter will provide the conclusions of the research and offer recommendations on how sustainability could be better integrated in the renewable energy transition in developing countries such as Cameroon.

Chapter 2

Research Framework and Methodology

2.1 Research Questions

The initial introduction of this paper highlighted some problems with sustainable energy development in Cameroon despite its high reliance on renewable energy sources such as biofuels and hydroelectricity. Evidence suggests that the low electricity access situation in Cameroon is hindering economic growth and that the reliance on traditional energy sources is detrimental to the health of humans as well as the environment. To further explore the relationship between Cameroon's renewable energy development and the problems that are occurring the following research questions will be explored in this study;

- What are the problems with renewable energy development in Cameroon?
- Why are these problems occurring?

In order to determine how best to mitigate unsustainable energy development and offer solutions a theoretical framework will be utilized to better understand the main factors responsible for inhibiting sustainable energy development.

2.2 The Study Area

Cameroon is located in central-western Africa and shares borders with six other African nations which include Nigeria, Chad, Central African Republic, Equatorial Guinea, Gabon and the Republic of the Congo. Cameroon's current territory has a recent history as it was once two separate colonies ruled by France and England as French Cameroun and English Cameroon. Cameroon declared its independence on January 01, 1960, however full unification between the two previous colonies did not occur until 1972 (The Commonwealth, 2019). Cameroon's population is 24.05 million and its GDP was approximately 34.8 billion in 2017 making it a lowermiddle income country (World Bank, 2016). Cameroon's two official languages are French and English, although there are some estimated 250 different ethnic languages spoken in Cameroon which is one of the reasons why it has earned it namesake as "Africa in miniature". Cameroon is divided politically into ten regions (Figures 2.2). Cameroon's capital is located in Yaoundé in the Central region. The North West and South West regions have an English majority while the rest of the country is predominantly French-speaking majority. The region of Littoral is home to Doula which is the economic capital of Cameroon and an important sea port for international trade. The period of the study will begin from the 1950s to current day as hydro development started in 1953 with the completion of the Edéa power station.

Figures 2.2: Maps Showing Major Cities and Regions Cameroon

Source: Central Intelligence Agency, 2019

Source: Ebong & Levy, 2011

Poverty remains an issue in Cameroon with 29.4% of the population living on $1.90 (2011 PPP) a day (World Bank, 2016). Cameroon is also ranked 152 out of 180 in the Corruption Index (Transparency International, 2018). Cameroon has historical been one of the African nations fortunate to enjoy a long peaceful period, however, today new and older conflicts are threatening this precarious peace. Tensions left by this colonial rule still exist today between the two dominant language groups. Cameroon's presidential elections took place on October 07, 2018 and resulted in the re-election of Paul Biya who has now served as president of Cameroon for 36 years, making him the second longest ruling African leader. The election was fraught with allegations of misconduct where many English-speaking Cameroonians alleged to be too scared to vote. The election results show voter turnout in English-speaking regions was only 10%, much lower than French-speaking areas (Maclean, 2018). There seems to be a proliferation of English separatism in Cameroon which might be fuelled by low electricity access in marginalized English-speaking areas. Figure 2.3 illustrates one such anglophone protest that occurred in October 2017 which aim was to promote the independence of English-speaking Cameroon in order to one day separate to form its own country. Another more severe threat is the existence of the Boko Haram to the North that carry out its activities in a low intensity war (International Crisis Group, 2018). In its wake, thousands of migrants have left the Northern region, and Cameroon is also host to many refugees from neighboring countries adding more strain on the system.

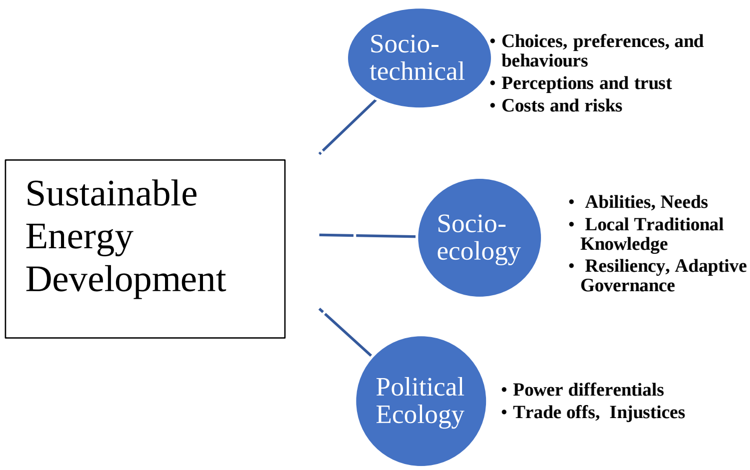
Figure 2.3: Increased Separatist Sentiments Among English Minority

Source: Chothia, 2017

2.3 <u>Conceptual Framework and Explanation</u>

Three different theories, socio-technical, socio-ecological and political ecology provide alternative explanations for Cameroon's incapacity to meet the modern energy access challenge. All these theories are complex system approaches; however, they differ in what they consider to be the most important aspects of how beneficial change can be implemented and sustained. Figure 2.3 outlines the main conceptual factors that affect sustainable energy development according to each theoretical system. For socio-technical theory; choices, preferences, behaviors, perceptions, trust, costs, and risks all influence successful adoption and dissemination of renewable energy technologies. Socio-ecology theories highlight that local abilities, needs, traditional knowledge, adaptive governance systems, and resiliency are essential components of sustainable energy development. Finally, political ecology argues that power differentials, trade-offs, and injustices can hinder sustainable energy development from taking place.

Figure 2.3: Conceptual Research Framework



Source: Own illustration, 2019

2.3.1 <u>Socio-technical Theories</u>

Sociotechnical theories highlight the relationship between technology and its infrastructure which "co-evolves with socio-economic institutions, actors and social norms (Goldthau, 2014, 134)." The idea of sociotechnical systems was first proposed by Trist and Emery (1965) in their research on coal mines in England. An important aspect of this theory is social innovation or the social shaping of technology which is a change in behavior that comes with the introduction of new technology. Changes in behavior can often be promoted by system changes of governance, laws, and regulations on both sides of supply and demand processes. Transitioning to renewable energy technologies is a major sociotechnical change where political and cultural factors need to be taken into consideration for consequent knowledge systems, norms, and behavior to shift (Stirling, 2014). However, these complex social systems are difficult to influence and the status-quo may produce inertia against change. For example, in Japan after the Fukushima nuclear disaster in 2011, researchers found that even after such an event a move from a centralized nuclear energy system to a decentralized renewable energy system was not occurring (Mclellan, Chapman, Aoki, 2016). Cameroon may be experiencing socio-technical barriers to the widespread adoption of renewable energy technologies such as solar energy and mini-hydro.

The perception of renewable energies in the form of social acceptance is a key factor in the successful implementation of renewable energy projects according to many authors (Devine-Wright, 2009; Wüstenhagen *et al.,* 2007; Mallett, 2007). Perceptions can be defined as a spectrum of evaluations that encompass views or feelings and that are influenced by culture, knowledge, and beliefs. Perceptions matter in the realm of renewable energy because RE projects are smaller, more visual, and closer to communities than conventional forms of energy that are far away from city limits (Wüstenhagen *et al.,* 2007). Where public knowledge of RE projects and their effects are low, local resistance can sometimes take place in the "not in my backyard symptom" or "NIMBYism." In numerous studies, insufficient public consultation has been shown to increase the likelihood of conflict between project implementers and the public (Amigun *et al.,* 2011; Haggett, 2011; Devine-Wright, 2009). The reasons for this are that projects that are implemented in the public space affect the locality in rarely solely positive ways. Trust can also influence public consent or descent. Another study found that when trust was high, there was little to no public engagement in the issue, in contrast to when distrust was prevalent, engagement was higher (Smith *et al.,* 2013). This misconception means that opposition to the project is more likely to occur when trust is low which could have the potential to halt or impede RE projects. Outsiders are especially perceived as untrustworthy, where private contractors instead of the community are engaged with RE development.

In developing countries, the costs and risks of transitioning are a major impediment to adopting RE technologies (Reddy & Painuly, 2004). For example, RE projects and technologies have high start-up costs that many families in the developing world cannot afford without microloans as a subsidy. The return of an investment in RE technologies, sometimes takes years to accrue, which is an impossible investment for people that live hand to mouth (Mallett, 2007). To combat this barrier, subsidies, incentives, and regulation could be put in place to increase the attractiveness of

RE technologies. However, these policies need to be put in place by stable institutions, good governance, and low levels of corruption, all of which are difficult to maintain in the developing world (Reddy & Painuly, 2004). Therefore, according to the rationale behind socio-technical theories, Cameroon could be facing a problem with transitioning to modern and sustainable energy systems that are accessible to everyone because of barriers with changing norms and behavior. However, other theories argue that factors such as the environment, power, and inequality differentials are more influential in how energy systems are organized and implemented.

2.3.2 Socio-ecological Systems

Another type of system approach called socio-ecology reinforces the importance of nature for shaping human society. Socioecological systems are complex adaptive systems composed of human and non-human entities that interact within networks (Levin *et al.*, 2013). The similarities between socio-technical and socio-ecological frameworks are that they both "use multi-scale perspectives to examine complex and dynamic systems and recognize the principles of adaptability, transformability, and the importance of continuous learning and knowledge within the system to allow these processes (Hodbod & Adger, 2014)." According to Smith and Stirling (2007) they differ in their objectives, views of progress, and how each theory frames root problems. Furthermore, ecological systems research has spatial dimensions and are subjective while socio-technical systems are non-spatial and normative which means that the desirability of promoting transitions and transformations is a given without questioning the unique views of different sub-groups and individuals (Smith & Stirling, 2007). Social–ecological systems are more neutral on desirability by focussing on ecosystem services and how detrimental ecosystem change affects these services. Cultural values difference for each person (Hodbod & Adger, 2014). In socio-ecological systems individual behaviors are interdependent as they adapt to change in their social and ecological environment. Responding to change is an important aspect of socio-ecology as ecological systems are never static but constantly undergoing transitions. When ecological systems change drastically such as with the case of climate change and other instances of environmental degradation, essential environmental services such as water and soil quantities and qualities deteriorate which jeopardizes livelihoods.

To mitigate these drastic changes, the method of resiliency has been promoted in the developmental field. Resiliency is the ability of a population to respond to change in a positive way while facing barriers, stressors, and outside forces beyond their control (Berkes, 2009; Coaffee, 2008). Adaptive governance or adaptive co-management are types of methods that can be utilized to increase resiliency by mitigating environmental change from a local, regional, and global level (Gaudreau & Cao, 2015). This approach recognizes local or traditional knowledge which together with scientific knowledge improves the knowledge base of development planning (Baird, Flaherty, Baird, 2005; Colding & Folke, 2000). Local knowledge can also be known as lay knowledge and traditional knowledge can also be called indigenous knowledge, subsistence knowledge, or ecological knowledge. Examples of these types of knowledge include understanding of the properties of plants, animal migrations, and other patterns in the environment that was essential to know and understand for survival. Local traditional knowledge (LTK) is defined as a specific knowledge process and way to see the world by a local group of people adapted to their environment and tested throughout generations, which has allowed them to survive, thrive, and develop their own identities and culture (Blaikie *et al.*, 1997; Berkes *et al.*, 2000; Taylor & de Loë, 2012). A lack of community participation results in LTK being unheard or ignored which is detrimental to development projects as proposed solutions often fail to understand the local context, needs, and capabilities.

Energy is a type of resource and many authors argue that social-ecology is a pertinent framework that can be utilized to better pursue resilient energy development (O'brien, O'keefe, Rose, 2007; Hodbod & Adger, 2014). O'Brien and Hope (2010) defines a resilient energy system as being "based on indigenous renewable resources, capacity enhancing, adaptable and upgradable and easy to repair and maintain (O'Brien & Hope, 2010, 7556). They argue that human development could be optimized if energy sources were locally owned and managed. Cameroon could also be facing difficulties with effectively managing their own renewable energy system and responding to change such as rapid urbanization, climate change, and environmental deterioration which is negatively affecting socio-economic development. A final theory explains how power relations shape trade-offs of renewable energy development.

2.3.3 Political Ecology

A third set of theories under the framework of political ecology adds the importance of power relationships and inequality to explain how humans interact with the environment. Power relations in society decide the actors that own resources who benefit and marginalized groups that face the repercussions from resource extraction and use (Forsyth, 2003). A subset of political ecology called Urban Political Ecology (UPE) illustrates how power differentials are translated into different levels of well-being in cities where the rich attain privileged living conditions while the poor live in the periphery with little control over local resource management (Heynen, 2014). According to this view solutions to energy problems should involve multi-sector and intergovernmental actors as stakeholders' often have conflicting interests and views on sustainability. For example, tradeoffs between choices such as preserving natural beauty or cultural sites of importance and economic gains of new development change from person to person and are subjective.

Calzadilla and Mauger (2018) argues that a transition from traditional or conventional energy systems to renewable energy systems needs to also be a transition not only in terms of technology and decarbonization but also in justice, inequalities, and power differentials. They study four case studies of solar and wind energy projects specifically concentrating on energy injustices that occur in developing countries when economic values are given a higher value than social wellbeing of the local inhabitants directly impacted by these projects. They show that "in the current energy system, poorer, excluded and less powerful social groups such as immigrants, minorities and poorly educated people are disproportionately affected by the siting of energy production facilities (Calzadilla & Mauger, 2018, 241)." They illustrate that renewable energy projects share similar problems as conventional fossil fuel extraction such as inequitable burdens and benefits of energy supply (distributional injustice), disrespect for people and cultures directly impacted by the development of renewable energy projects (recognitional injustice), and a lack of genuine information and public participation processes (procedural injustices).

Injustices local communities face as a result of renewable energy development such as hydropower projects has ranged from loss of livelihoods, ecosystem disturbances, food insecurity, displacement of people, social conflicts, and violation of cultural and indigenous rights (Farfan, Peltoniemi, Breyer, 2018). Biofuel production also has resulted in recognitional injustices, where projects often use the term "wasteland" to highlight that development is occurring and give the illusion to benefits but this land may have strong value for local communities. Procedural injustices include a lack of community consent such as when environmental impact assessments of the project remain unavailable to the public (Ndi, 2017). A political ecology framework could illustrate if injustices are occurring in Cameroon which is hindering sustainable renewable energy development. Also, a center-periphery perspective would highlight if renewable energy development has resulted in unequal distribution of benefits and costs between income groups as differences between the urban/rural divide.

To further understand the reasons that sustainable energy development is prevented in Cameroon, each of the three theories will be utilized to assess their validity in the Cameroon context. Improving the ability to recognize the social, cultural, ecological, and political processes involved in renewable energy development can allow researches and policy makers to better understand the root problems and barriers that hinder sustainable energy development from occurring.

2.4 <u>Research Methods</u>

The proposed research will analyze renewable energy development in Cameroon to highlight the problems involved that create challenges for sustainable energy development. The first segment of the research will be an analysis of the process of energy development, specifically renewable energy in Cameroon from its pre-independence to current day initiatives and plans. This endeavor will be important to understand historical and institutional change that could affect future energy development in order to grasp potential limitations and problems that could arise. To better understand the problems of renewable energy development in Cameroon and why these problems are occurring an analysis of secondary data will be performed. Quantitative data such as electricity access rates, deforestation statistics, and health indicators such as the prevalence of indoor air pollution caused by traditional energy use. Online database systems such as the World Bank, IEA, Human Development Index, and Cameroon's data portal will be utilized to assess these indicators. Qualitative data from reports produced by the UNDP and Amnesty International will also be used to verify injustices occurring in Cameroon on a social and political level.

To answer the second research question of the reasons why these problems are occurring, the three theories outlined in the conceptual research framework; socio-technical, socio-ecological, and political ecology will be applied to determine which theoretical system best explains the barriers of sustainable energy development in Cameroon. Extensive searches using the University of Ottawa library portal as well as Google Scholar and other search engines such as PAIS Index and Pro Quest will be utilized to formulate theories based on secondary sources. Key words such as urban energy, resilient energy systems, local energy, and conflict in renewable energy transitions will allow for comprehensive understanding of related issues and current events of energy systems in both developed and developing countries. Finally, recommendations will be made by attaining a comprehensive structural analysis of the problem of energy access and the barriers that prevent it on a local, regional, and global level.

Chapter 3

Context and Challenges

3.1 Energy Development in Cameroon from 1950s to Present

Cameroon has the fourth highest energy potential in Africa, however, despite this energy wealth Cameroon's energy consumption is below average for the region (Wandji, 2013). It is estimated that 80% of population do not have access to the national electric grid (Wirba *et al.*, 2015) . As electricity levels are low, traditional energy in the form of biomass holds the largest share of energy consumption. There is an energy shortage in Cameroon because of limited energy supply and increased energy demand (Adom, 2016). Energy demand was 1455 MW[8] in 2014 (Muh, 2017) and is projected to increase by 5000 MW in 2020 due to population growth which will put even more pressure on the energy system (Mas'ud *et al.,* 2015). The Cameroon government plans to implement projects to increase energy supply by 2500 MW between 2012 to 2020, but these plans have not been fully successful (Ayompe & Duffy, 2014). Cameroon's national policy goal of becoming an emerging economy by 2035 is put in jeopardy by the precariousness of its energy sector which negatively effects economic growth. Many energy sources exist in Cameroon. A brief history and current status of each energy source will provide the information necessary to determine the problems associated with energy production in Cameroon that will be further explained in Chapter 4.

3.1.1 Oil & Gas

Oil exportation in Cameroon began in 1977 which contributed to high national economic growth rates because of a boom in oil prices and demand world-wide during the period between 1979-1985 (Djiofack & Omgba, 2011). Cameroon's current oil reserves have been diminishing since 1985 with estimates in 2010 of total reserves of 30 million tons (Tamba, 2017). However, Cameroon remains the 6th largest crude oil producer in Sub-Saharan Africa, with an average of 76,000 barrels of crude oil a day according to the United States Energy Information Administration

[8] The watt (W) is a symbol used to measure power at one joule of energy per second. A kilowatt (kW) is equal to one thousand watts and a megawatt (MW) is equal to one million watts.

(USEIA). Cameroon's gas reserves are also moderate at 4.8 tcf[9] and is globally ranked 47th on the list of the world's largest gas reserves. (EIA, 2018). An important aspect of oil and gas development in Cameroon is the Cameroon-Chad pipeline which is the largest foreign investment project in the country (Figure 3.1). The pipeline transfers oil reserves from Chad through Cameroon which has access to sea ports. Oil is mainly utilized in the transportation industry, however, electricity from thermal gas plants powered by oil and gas supplements Cameroon's hydroelectricity. Thermal plants include Limbe, Yassa, and Kribi among others. Besides electrical production, kerosene (propane gas) is also used for cooking and lighting.

Figure 3.1: Map of Cameroon-Chad Pipeline

Source: Badgley, 2010

3.1.2 Hydro Energy

Hydro-electric development in Cameroon began in 1953 with the completion of the Edéa power station which has a capacity of 263 MW. The majority of the hydro dams are located on the Sanaga river basin which is the main hydropower source of Cameroon. Both Edéa and Song Loulou (388 MW) are on the Sanaga, producing 97% of Cameroon's hydropower supply. Lagdo (72 MW) is located in the north of Cameroon near Garoua. Hydroelectricity is responsible for 73% of all electricity produced in Cameroon (Muh, Amara, Tabet, 2018). However, Cameroon's hydro-

[9] Trillion cubic feet (tcf).

electric system becomes vulnerable to blackouts during the dry seasons when water levels are low. Electricity rates range from 65-88% in urban areas, while the rural hinterland remains at low access levels of 14%. There are three electrical grid networks in Cameroon. These grids are; the Northern Interconnected Grid (NIG), the Southern Interconnected Grid (SIG), and the Eastern Isolated Grid (EIG). Each grid supplies electricity to their respective geographic region in their name, with the (NIG) supplying electricity to the North of Cameroon, SIG to the South and (EIG) to the East. Cameroon has the second largest hydro energy potential in Sub-Saharan Africa after the Democratic Republic of the Congo, however, only 5% of hydropower potential of Cameroon is harnessed (Muh *et al.*, 2018).

Figure 3.2: Lom Pangar Dam

Source: World Bank Group, 2019

The state-owned company the Société Nationale d'Electricité du Cameroun (SONEL) which originally controlled hydro-electrical development turned to American ownership under the company AES in 2001. This privatization promoted concern to some academics because it caused a monopoly to form with insufficient regulation to ensure that affordable and equitable electrical access would occur (Pineau, 2002; Imam *et al.*, 2018). In 2014 AES-SONEL was bought by a British investment firm and renamed Eneo which is directly responsible for managing the electrical system (production, transmission, and distribution) of Cameroon. Privatization under foreign ownership has failed to increase access levels to electricity in Cameroon, and current electricity supply is unable to meet the electricity demand of the population especially during peak periods. In addition, large rural areas of Cameroon are not covered by the central hydropower lines which increases the urban-rural divide. Hydro production is a key facet of future plans for economic development for the government of Cameroon with numerous dams under construction or in the planning stages. One such hydro development, Lom Pangar with a capacity of 30MW (Figure 3.2) is supported and partially funded by the World Bank who argues that the increased electrical generation would benefit economic development in Cameroon (World Bank, 2015). However, in 2005 a report from a local civil society organization Global Village and a non-governmental organization (NGO) International Rivers highlighted the risks involved with this dam which included flooding of forest ecosystems as well as unknown consequences on the Sanaga River which increases Cameroon's vulnerability to droughts. (International Rivers, 2005). Other hydro development projects in progress include Natchigal and Menve'ele dam, as well as the rehabilitation of the Song-Loulou and Edéa power to increase electrical power supply to Cameroon. Cameroon also has a huge potential for mini-hydro (estimated at 1.115 TWh[10]), mainly in the western and eastern regions. However, these small hydro potentials are poorly utilized.

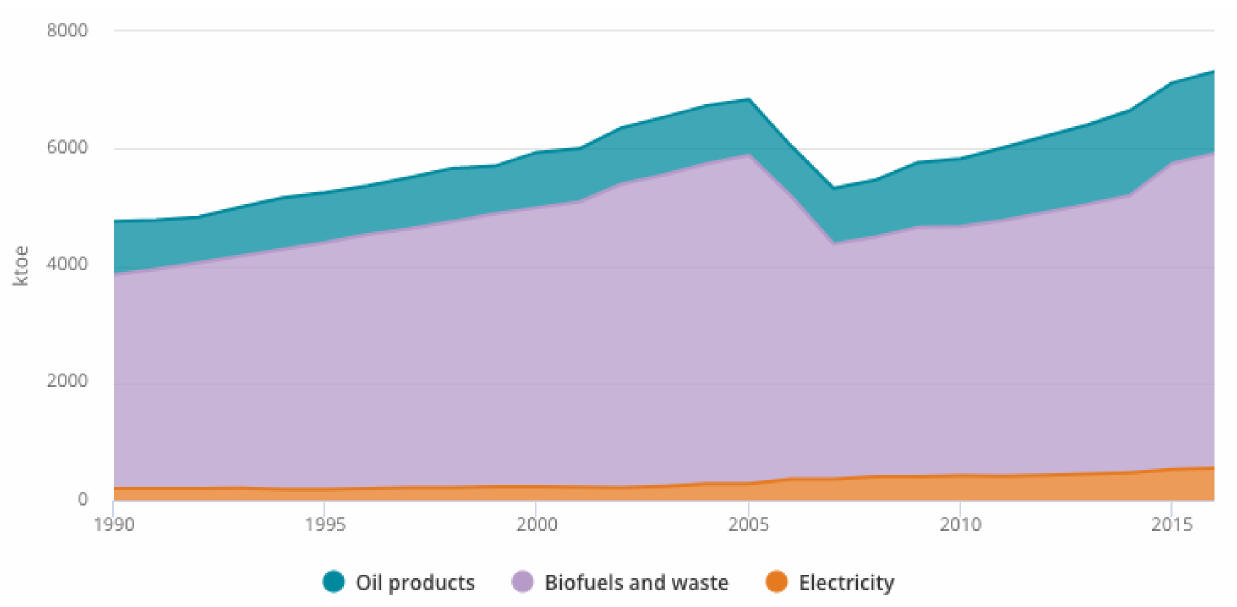
3.1.3 Biomass Energy

The majority of biomass energy consumption in Cameroon constitutes as traditional energy in the form of fuelwood or animal matter. As depicted in Figure 3.3, biomass energy holds the largest share of final energy consumption in Cameroon and has reached consumption levels similar to the previous decade. Fuelwood is cut from trees taken in areas such as the Congo Basin which runs through southern Cameroon and is the 4th largest tropical forest in the world (Greenpeace, 2018). However, as half of the Congo Basin is under commercial logging leases the extent of the forest ecosystem is at risk. Cameroon holds the 3rd largest biomass potential in Sub-Saharan Africa as three quarters of territory is covered in 25 million hectares of forest (Mas'ud *et al.*, 2015). Furthermore, as approximately 70% of Cameroon's workforce is in the agricultural sector, substantial agricultural residues could be used for biofuel production (Molua & Molua, 2007). Biofuel production in Cameroon has been viable since 2005 from palm oil cultivation. The biofuel

[10] A kilowatt hour (kWh) is the amount of energy used in one kW of power sustained for one hour. A terawatt is equal to 1 trillion watts. Therefore, a tera-watt hour (TWh) is the amount of energy measured in 1 trillion watts that can be generated in one hour.

sector is predominately controlled by foreign-owned companies which has negatively affected local communities. According to one researcher land grabbing for palm oil plantations has occurred with little to no community consultation of the land directly implicated and that these deals often occur in secret between government officials and foreign owned companies (Ndi, 2017). Biomass energy in the form of fuelwood is largely unregulated in Cameroon with extensive illegal logging that occurs further hindering sustainable energy development and leading to deforestation.

Figure 3.3: Cameroon's Total Final Consumption (TFC) by Source 1990-2016

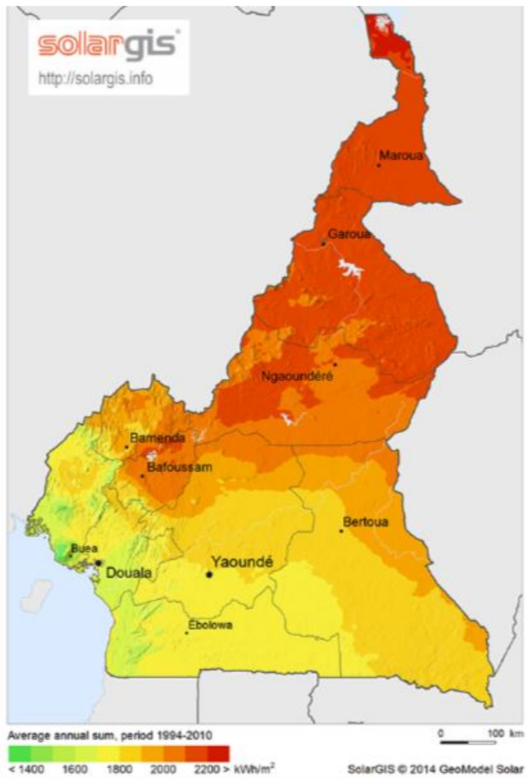


Source: IEA, 2016

<u>3.1.4 Solar Energy</u>

The solar energy potential in Cameroon is vast as illustrated by Figure 3.4, however this potential has not been exploited (Ayompe & Duffy, 2014; Mbi, 2013; Abanda, 2012). Solar energy could provide an effective way to meet the lag in hydro-electric generation in dry seasons, when the sun rays are more powerful. The current application of solar energy in Cameroon is to the power telecommunication network, as well as other small pilot projects. For example, there has been recent developments of city solar lighting installments in the big urban centers of Yaoundé and Douala (Muh *et al.*, 2018). There are many barriers to effective solar energy implementation as current installations are not well maintained, they require high start-up costs, and furthermore, there has been little government commitment to boost the sector which has led to a lack of local and international investors. Recent large-scale solar energy development projects ranging from 100 to 500 MW are on the planning stages which include JCM Greenquest, Joule Africa, and GSC Energy. The newly named company Eneo has also launched themselves in the solar market with the new opening of Djoum a solar-thermal "hybrid" station using both solar electricity and thermal electricity (Enerray, 2018).

Figure 3.4: Global Horizontal Irradiation[11] in Cameroon (kWh/m2)



Source: Solargis, 2014

The government of Cameroon is not actively promoting solar energy as polices are limited such as a cancelation of the value added tax on solar energy technology, where more subsidies are required to financially support the sector. In terms of international projects, the phenomenon of

[11] Global Horizontal Irradiance (GHI) is the combined value of solar radiation that comes directly from the sun to the earth's surface and diffused radiation which is radiation scattered by molecules and particles in the atmosphere that comes to earth in all directions.

donor fatigue has resulted in solar projects that ultimately failed due to poor maintenance and local management. For example, an ignorance of local needs and capacity building during program implementation negatively affected project outcomes in remote villages in Cameroon (Nfah & Ngundam, 2009). Foreign companies are also starting to become involved in solar energy production. In Garoua which is the capital of North Cameroon a solar photovoltaic contracted by the Italian company Enerray is being constructed with a capacity of 30MW (UniAfrica, 2017)**.** Another solar electricity system opened in Nsem funded by Chinese finance in 2018 (Funwie, 2018)**.** Local small-medium enterprises (SMEs) are lagging in the solar energy sector, however one business started by a young entrepreneur Bolivie Wakam called Africa Solar Tech is making some headway (Journal du Cameroun, 2017).

3.1.5 Wind, Geothermal, and Tidal Energy

Wind energy potential varies throughout the country with Northern Cameroon at higher wind levels comparable to the rest of Cameroon. However, for large scale projects the wind speed is not high enough to maintain energy levels (Abanda, 2012). Geothermal energy potential is not well known in Cameroon as few studies have been undertaken. The potential for tidal energy which is energy derived from the rise and fall of sea levels in Cameroon is also not well known or studied.

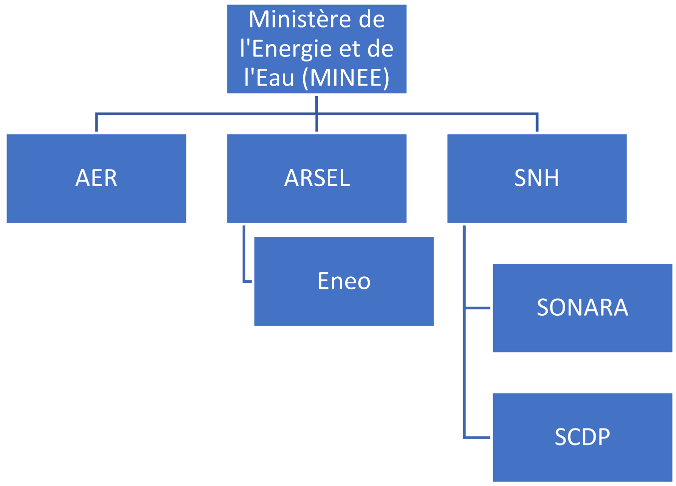
3.2 Cameroon's Energy Governance Structure

In Cameroon the organizational structure around energy governance comprises of numerous actors and regulatory bodies (Figure 3.5). The Ministry of Energy and Water "le Ministère de L'Energie et de L'Eau" (MINEE) is the governmental body charged with developing energy policy and regulations. MINEE cites electricity access in Cameroon as only 28.5% nation-wide and that this negatively effects Cameroon's development in sectors such as housing, education, health, and the development of small-medium enterprises (SMEs), which is detrimental to social and economic development of the country as a whole (GTNM, 2018). As a national policy goal, the Cameroon government since 2006 has been working on a multi-sectoral approach called the "Groupe de Travail National Multisectoral (GTNM)" which aims to share data and increase capacity-building of governmental actors to work towards continued electrification, especially in rural areas.

L’Agence de regulation du secteur de l’èlecticité (ARSEL) was created by law in 1988 and is responsible for regulating and monitoring the electricity sector by setting electricity rates and determining electrical standards (ARSEL, 2018). Another, agency named the l’Agence d’électification rurale (AER), specifically concentrates its resources to the improvement of electricity sources to rural areas. Finally, the Electricity Development Corporation (EDC) was created in 2006 to promote electricity development in Cameroon.

Electricity tariffs are established at the national level by a joint decision of the Ministry of Energy and the Ministry of Trade in agreement with Eneo and ARSEL. In addition, three institutions are specifically involved with the regularization and implementation of oil and gas. The Société nationale des hydrocarbures (SNH) implements all the research and development of the sector on behalf of the state. The Socièté national de raffinage national (SONARA) is responsible for providing the national market with refined petroleum. La société camerounaise des dépôts pétroliers (SCDP) stocks petroleum products in distributing centers across Cameroon. Finally, La caisse de stabilisation des prixs hydrocarbures (CSPH) was created in 1974 with the unique mandate to stabilize the price for the distribution of refined petroleum products. Eneo has an agreement with the Cameroon government to be the sole provider of producing and distributing electricity and is therefore a monopoly. On October 8th, 2018 an agreement signed in Doula by the Ministère de l'Emploi et de la Formation professionnelle (MINEFOP) agreed that Eneo would become a major gas supplier for Cameroon. With this agreement Eneo is now diversifying into gas where it already controls hydro-power in Cameroon. There is not currently an institution that exists to regulate the renewable energy sector in general which hinders growth in the renewable energy sector (Tamba, 2017).

Figure 3.5: Hierarchy of Energy Sector Regulation in Cameroon



Source: Adapted from ESMAP, 2007

3.3 Government Policies

The policies concerning energy development in Cameroon are numerous. Cameroon's Growth and Employment Strategy Paper (GESP) which concerns the ten-year period from 2010-2020 was heavily concentrated on energy for development with a target of 3000 MW of additional installed hydropower capacity has been set for 2020. This involves the development of new power generation facilities (mainly hydro), modernization of the national electricity network which includes infrastructures, and the promotion of modern and clean energy services, especially for rural communities. Furthermore, an Energy Sector Development Plan 2030 was developed which goal is to increase electricity access to 75% total and 20% rural electrification rate. Another plan, named the Rural Electrification Master Plan (REMP) goal is to electrify 660 localities with grid extensions and mini-hydro, through a diversification framework (Muh *et al.*, 2018).

The link between energy and poverty was recognized in 2007 in a National Energy Action Plan for Poverty Reduction (NEAPRP) which main goal was to increase access to modern energy services for social infrastructure such as education and health facilities. The plan highlights energy poverty as a detrimental factor to human development in Cameroon. Throughout the report the importance of electricity in lighting, communications, and technical services as well as more efficient and safe cooking technology such as "les foyers améliorés[12]" which translated means improved oven was promoted. Specifically, the framework of the Millennium Development Goals (MDGs) was used throughout the document to highlight the positive linkages between improved access of energy services to human development. In Cameroon, the reaction to the MDGs was the creation of the Document de stratègie de reduction de la pauvretè (DSRP), which is their national poverty reduction plan, however the strategic plan failed to identify and utilize energy as a significant factor in reducing poverty and increasing human welfare. According to NEAPRP, replacing traditional to modern energy for cooking purposes is both a public safety, health, and women empowerment goal (ESMAP, 2007, 35).

3.4 The Energy Gap

Cameroon is rich in energy resources, and therefore the deficit in energy supply to meet energy demand cannot be accounted to a lack of energy resource potential in Cameroon. Poor management, regulation, and promotion of the energy sector by the Cameroon government is the main issue at stake according to many experts (Mas'ud *et al.,* 2015; Adom, 2016; Tamba, 2017; Wirba *et al*., 2015). Cameroons electricity needs are mainly covered by hydropower. This reliance on a single energy source gives rise to Cameroon's energy insecurity and the observed regular power shortages, particularly in remote and semi urban areas. Insufficient access to modern energy such as electricity results in the continued reliance on traditional energy use which results in problems that will be covered in subsequent chapters. Sustainable renewable energy development could be a major factor in fueling development in Cameroon. However, access to modern energy remains an issue that effects economic and socio-economic growth and hinders development in Cameroon. Increasing energy access levels while transitioning to a low carbon energy infrastructure are twin conflicting challenges. Cameroon unfortunately has a deficit of governance coordination and action which hinders sustainable renewable energy development. Off grid solutions to improve resilience and accessibility as well as government regulation to promote RE development could meet the energy deficit of Cameroon's population.

[12] Improved cookstoves are devices have a more efficient heat transfer, emit less emissions, and are safer than traditional open pit stoves.

Chapter 4

Consequences & Theoretical Explanations

This chapter is divided into two parts in order to answer the research questions. First, an analysis of the consequences of RE development will be explained in Cameroon in order to answer the first research question. Topics covered include socio-ecological effects of RE development as well as the consequent impacts on water and food security. The health consequences of traditional energy which impacts the relationship between energy poverty and gender will be explored. In addition, the linkages between RE development and the urban environment will be explained which further shapes how inequalities and violence result from power differentials and trade-off decisions.

The second part of this chapter will answer the second research question by assessing the reasons why these consequences are occurring. In order to accomplish this, an analysis of the theoretical framework outlined in Chapter 2; socio-technical, socio-ecological, and political economy systems will be utilized to assess which theory is the most comprehensive explanation for why these problems are occurring in the context of Cameroon. A clear understanding of the factors described in each framework that are the most responsible for further aggravating the consequences of RE development in Cameroon is necessary to inform policies and improve sustainability energy development in the future.

4.1 Problems with Renewable Energy Development in Cameroon

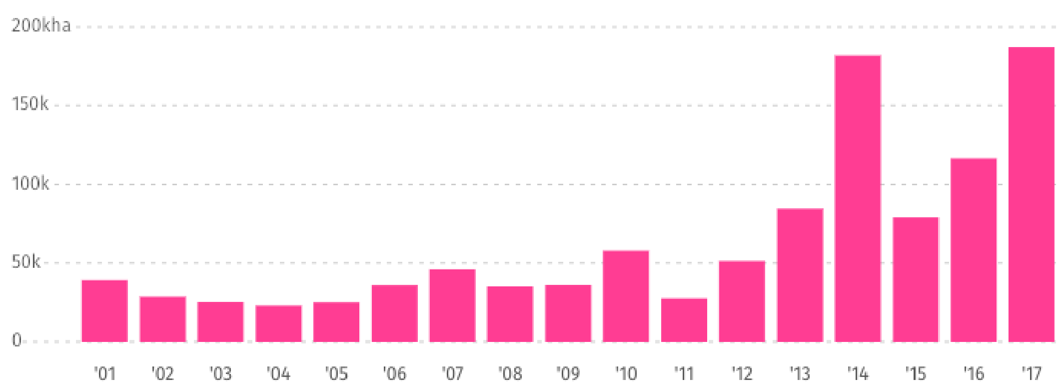
Research Question 1: What are the problems with renewable energy development in Cameroon?

Hydro and biofuel development in Cameroon have both caused detrimental effects to the socio-ecological environment. Furthermore, health, gender, as well as socio-economic impacts on development in terms of education are all negatively impacted from the continued dependence on traditional bioenergy such as fuelwood. The unsustainable development of renewables in Cameroon affects food and water security further compounding issues of vulnerability as well as precariousness. In addition, expanding power differentials in Cameroon and the consequent unequal distribution of benefits and costs of renewable energy development results in many forms of injustices that negatively affect the well-being of local communities as well as the livelihoods that they depend on.

4.1.1 Socio-ecological Effects

Environmental degradation occurs from conventional energy development as well as renewable energy development. Large-scale exploitative projects cause negative externalities and if these are not properly mitigated, severe consequences can occur to socio-ecological systems. Forest cover in Cameroon was once 280 Mha in 1965, however, biomass exploitation for fuelwood has attributed to significant deforestation[13] in Cameroon (Gbetnkom, 2005). According to the Food and Agricultural Organization (FAO) of the U.N the deforestation rate in Cameroon has augmented rapidly, rising from 0.6% loss rate of overall forest cover per year from 1980-1995 to 0.9% between 1990 to 2010 (FAO, 2006). In addition, Cameroon has lost 1.08Mha of forest between the period from 2001 to 2017 as depicted by Figure 4.1. This loss is equivalent to a 3.4% decrease of forest cover since 2000 which amounts to 137 Mt of carbon emissions (Global Forest Watch, 2017). Approximately 19Mha of forest cover remains in Cameroon (FAO, 2016).

Figure 4.1: Tree Cover Loss in Cameroon from 2001 to 2017



Source: Global Forest Watch, 2017

[13] Deforestation is caused by humans to reduce tree cover in order to convert forest ecosystems into commodities such as timber and/or to increase the land available for agricultural and other land uses like residential housing due to urbanization, mining, or industry.

Illegal logging accounts for a large segment of deforestation which makes it difficult to effectively manage forest resources and assess their quality and quantity. The European Union (EU) recognizes the threat of illegal logging to protected areas and to mitigate this they created a forest partnership to stop the sale of illegal timber. This agreement is part of a Forest Law Enforcement Governance and Trade (FLEGT) program which the government of Cameroon signed with the EU in 2010 (African Union, 2010). The Congo Basin is an important tropical ecosystem that supports approximately 10,000 different kinds of plants, and more than 2000 different animal species including fish, birds, and mammals. Figure 4.2 shows the extent of the Congo Basin forest which covers territory in six countries. Cameroon has the second highest rate of deforestation in the Congo Basin after the Democratic Republic of the Congo (Greenpeace, 2018). Forests act as carbon sinks, reducing carbon emissions by converting carbon dioxide into oxygen supporting a healthy atmosphere. Tropical forests are also important ecosystems for many species and so deforestation threatens biodiversity. Cameroon is home to numerous species at risk, two that are critically endangered are the western lowland gorilla and the chimpanzee (African Wildlife Foundation, 2017).

Figure 4.2 Map of the Congo Basin Forest

Source: Molua, 2012

Biodiesel cultivation of palm oil has also caused deforestation in Cameroon as more agricultural land is required to grow crops (Gbetnkom, 2005). Continued deforestation for fuelwood and palm oil agricultural expansion also further exacerbates problems already occurring as a result of climate change which is beginning to impact almost all of Cameroon's sectors of development (Bele *et al.*, 2011). The forestry sector accounts for 6-10% of Cameroon's GDP, therefore deforestation without the equivalent tree planting to maintain the forest cover could lead to unsustainable consequences for the economy (Bele, Sonwa, Tiani, 2013). Coastal areas will be affected by rising sea levels and other natural disasters could become more prevalent because of climate change such as hurricanes and monsoons which can also negatively affect the agricultural sector by destroying crops. Deforestation also impacts livelihoods as desertification[14] and soil erosion inhibits agricultural production and may endanger human life by increasing the likelihood of landslides.

Hydro dams also have significant effects on the socio-ecological landscape. The Lom Pangar dam development in Cameroon resulted in flooding of the Deng Deng Forest[15] which has important ecological importance as one of the last hardwood forests in the continent. Interestingly, the part of the forest that was flooded was originally avoided by the construction of the Cameroon-Chad pipeline which costs were increased by avoiding the Deng Deng. Therefore, the dam made these costs obsolete and also increases the likelihood oil spills as the dam affects 20 km of pipeline already constructed (International Rivers, 2005). Ecological systems of animals such as fish, birds, as well as plants are also affected by hydro dam construction which has consequent effects on human livelihood strategies such as fishing and agricultural activities. For example, changes in sediment level due to dam development which floods land affects water chemistry which leads to ramifications on human health by making water non potable and can also increase the risk of extinction of certain species of fish. In Cameroon, the local community situated near the Mapé dam say that many of the fish species have disappeared due to the dam. Furthermore, the positive economic benefits of hydro development failed to reduce poverty of the local population (Mbih *et al.*, 2014). Alternatively, reservoirs can increase the potential for economic and leisure activities such as tourism and outdoor recreation. Agriculture may be improved from irrigation or flooding

[14]Desertification is a type of land degradation where the biological productivity of the land is reduced to such as extent that previous fertile land becomes dry and sandy, and soil is no longer able to support trees or agriculture.
[15] The Deng Deng forest is located in the Eastern region of Cameroon and comprises an area of 580 square km. It is a protected conservation area which is home to the largest population of northwestern lowland gorilla in the wild.

controls can be constructed to manage the variation of water levels during the dry and wet seasons. Lastly, perhaps transportation could be improved by reservoirs that are less treacherous than rivers (Tchouaha, 2012). Ecosystem services that forests offer such as clean water and air provision, as well as the maintenance of fertile soil qualities are important thresholds in socio-ecological systems because when these factors reach certain levels, they can cause feedback loops, resulting in rapid system changes that are hard to adapt to which can result in disaster for local communities that are dependent on the current system.

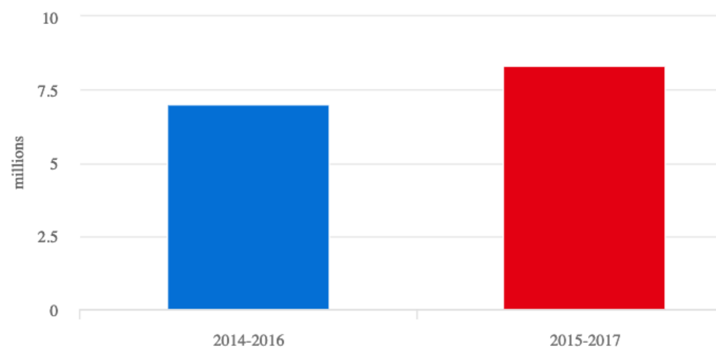
4.1.2 Water and Food Security

During a World Food Summit held by the FAO in 1996 a definition of food security was internationally recognized as follows;

''A situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2002).*''*

A report from the FAO called the State of Food Security and Nutrition in the World 2018 estimated that 821 million people were undernourished in 2017 (FAO, 2018), therefore, food insecurity continues to be prevalent in the world and is aggravated by water scarcity that is worsened by changes in climatic conditions. Water, food, and energy are all basic human needs. However, there are limits to their exploitation as many areas in the world are prone to water and food scarcity. The over-exploitation of natural resources can lead to the phenomenon of the tragedy of the commons where local resources of water or agricultural land are depleted to an extent that they are no longer viable. Another economic theory is the principle of tradeoffs where choices must be made between the production of different quantities of resources. For example, deciding between whither land should be used for crops and livestock for food or for biodiesel production such as palm oil (Magoni, 2017). As outlined in the environmental section, logging due to fuelwood exploitation and agricultural expansion leads to deforestation. Severe deforestation causes desertification to occur which results in soil erosion into water or being blown away from the wind. Desertification degrades soil quality and impacts food security. Furthermore, biofuel production from palm oil increases the run-off from fertilizers and other farming pollution which causes ground water salinization[16], negatively affecting water and soil qualities which also leads to food and water insecurity (Rockstrom *et al.,* 2009). Figure 4.3 illustrates how the population that was severely food insecure in Cameroon is worsening, increasing from 7 million in the three-year period between 2014-2015 to 8.3 million people from 2015-2017.

Figure 4.3: Number of severely food insecure people in Cameroon (million) (3-year average)



Source: FAO, 2017

Hydro-energy production can also affect the quantity and quality of water and food sources because rising water levels caused by hydro dams results in water salination and less agricultural land for crops. Climate change has also negatively impacted food and water security in Cameroon by increased weather pattern variability that has caused crop yields to become more unpredictable and even fail in some years (Molua, 2002). With approximately 70% of the workforce employed in agriculture this leaves Cameroon especially vulnerable to volatile and unpredictable weather patterns (Molua & Molua, 2007). Periods of drought worsened by climate change can exacerbate land and water conflicts. Renewable energy has impacts on these conflicts as well as decisions on trade-offs between crops used for biofuels or food production, and water use for hydro-electricity can increase food and water shortages (Minucci & Karmaoui, 2017). According to a UN report there are minor implications of climate change on Cameroon's hydroelectric development as the Sanaga River is highly climate resilient (Grijsen, 2014). However, rain variations have already reduced water levels of Lake Chad. A study on water qualities in the Logone Valley that is located

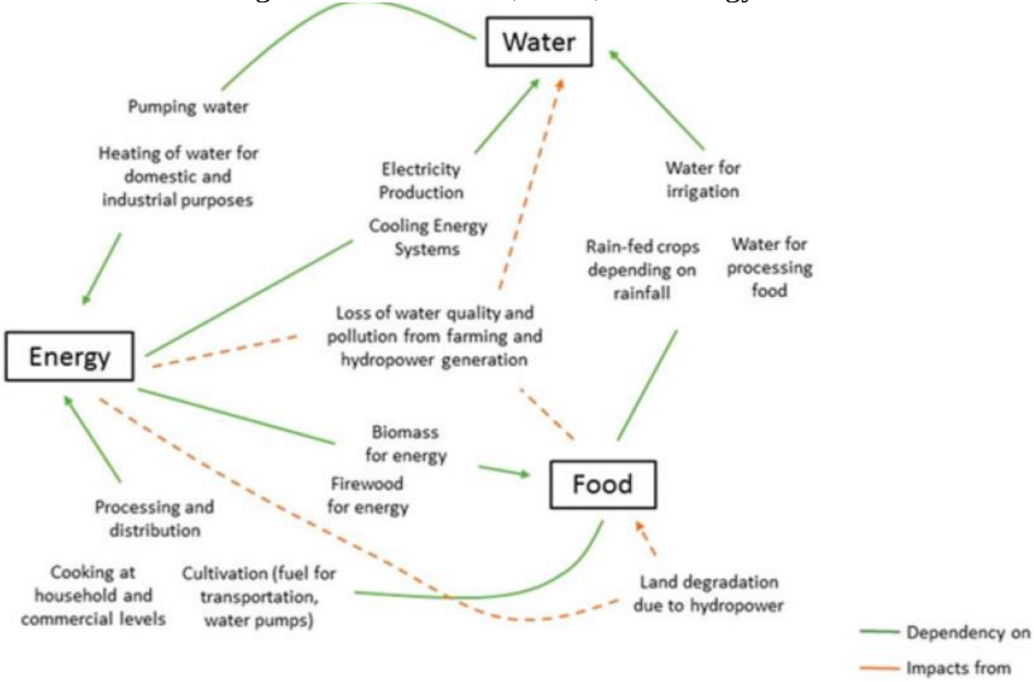
[16] Salinization is another form of environmental degradation process that increases the salt content in soil which eventually causes the soil quality to be toxic for plants. It can be caused by natural processes such as rises in sea level or the breakdown of geological matter. Inappropriate irrigation can also cause salinization of water sources and even underground aquifers which is detrimental to the provision of potable water and human health.

in both Cameroon and its neighbor Chad reports that the aquifers sampled contained elevated led levels which are dangerous for human health (Sorlini *et al.*, 2013).

The relationship between water, food and energy is contextualized in Figure 4.4 where each factor is dependent on the others, and how water and food quality are impacted from energy development. Numerous types of energy production are dependent on water. Electricity is produced from heating water to cause the steam required for thermal plants, and water is also used in cooling energy systems such as nuclear energy. On the reverse, potable water accessibility can be dependent on energy to pump and heat water to households, businesses, and industries. As explained previously, energy production can result in a loss of water quality due to both biofuel and hydro energy development. Water quality deterioration has consequent effects on food security due to salinization and drought. In relation to food, biomass energy is created from burning fuelwood and biodiesel production from agricultural crops. Deforestation can result in desertification and salinization which hinders the soil's ability to support crops, and agricultural crops used for biodiesel energy is limiting food supply (A. M. Colucci, 2016). Hydropower is not dependant on food, however the former results in land degradation from flooding which negatively effects food production. However, food security does require energy for processing and distributing food throughout the world. For example, in this era of globalization[17] energy is what makes it possible to have fresh fruits and vegetables in every season Additionally, cooking food requires energy and modern food production is extremely dependant on energy intensive machinery. The correlation between water and sufficient food production is apparent for proper cultivation, irrigation, and processing of food (Minucci & Karmaoui, 2017).

[17] Globalization is the unpresented movement of people and ideas due to innovation in communication and information technologies that has allowed investment, and trade of goods and services that result in global interconnection of markets and cultures.

Figure 4.4: The Water, Food, and Energy Nexus



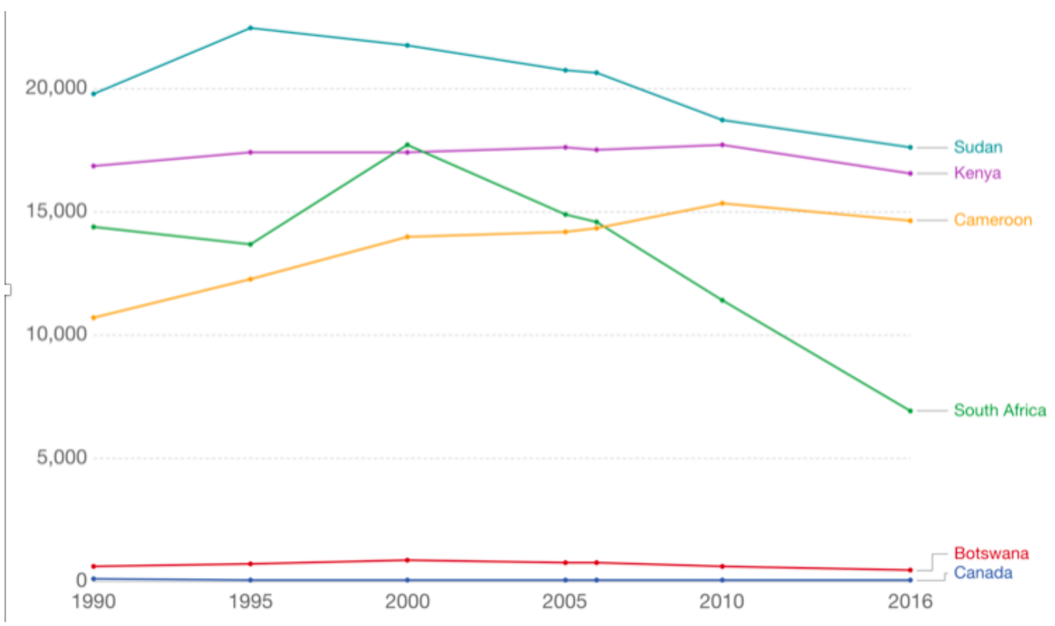
Source: Minucci & Karmaoui (2017)

The water, food, and energy interrelations are an example of a connected complex system where changes in one factor can affect the other, resulting in a further indirect effect on the third factor. This interconnection highlights that there may be tensions that exist between the agricultural, food, and energy sectors which consequently impacts human well-being.

4.1.3 Effects on Health

Burning traditional energy sources such as fuelwood has significant consequences on health. Indoor air pollution (IAP) can result in "acute respiratory infections, tuberculosis, chronic respiratory diseases, lung cancer, cardiovascular disease, asthma, low birth weights, diseases of the eye, and adverse pregnancy outcomes" (Sovacool, 2012, 275). The combined factors of indoor and outdoor air pollution have caused over 7 million people to live in conditions of unsafe air according to a State of Global Air report in 2018. Breathing polluted air has contributed to 6.1 million premature deaths due to diseases of the cardio-vascular system such as stroke, lung cancer, and heart attack (World Energy Assessment, 2000). In terms of the global burden of disease risk factors there are just three other forces that cause more harm globally which are high blood pressure, diet, and smoking. In Cameroon child pneumonia and chronic obstructive pulmonary disease are heavily linked with solid biomass burning for cooking and heating. A UNDP report called the *Energy Access Situation in Developing Countries* cited that in Cameroon 9,900 children under 5 died from pneumonia and 1,500 adults died from COPD in 2004 (UNDP, 2009). In addition to IAP, physical injury can occur during fuelwood collection including back aches from carrying heavy loads of wood over long distances as well as foot damage and wounds from accidents (Sagar, 2005). Figure 4.5 illustrates that the annual number of premature deaths attributed to illness as a direct result of IAP from the use of solid fuels for cooking and heating in Cameroon has risen steadily since 1990. This trend is in juxtaposition to Sudan which has reduced the amount of deaths attributed to IAP. Therefore, Sudan is converging on Cameroon while countries such as Botswana have successfully maintained low rates of deaths related to IAP that are similar to developed countries like Canada.

Figure 4.5: Absolute Number of Deaths from Indoor Air Pollution 1990-2016



Source: Roser & Ritchie, 2013

Inadequate access to modern energy services also results in a lack of refrigeration and proper lighting in health facilities which hinders proper vaccination as well as blood supply storage as well as the ability to perform surgeries and other lifesaving health activities. Information and communication technology also aid in the dissemination of health awareness. A lack of electricity to power computers and other electronic devices can reduce the effectiveness of mass media such as television and radio to promote sanitation norms; for example, condom usage to decrease the spread of disease such as HIV Aids (Sovacool, 2012). Furthermore, hydro reservoirs can act as a breeding ground for vector borne diseases such as malaria spread by mosquitos. Non-potable water due to hydro dams also increases the likelihood of waterborne illnesses. However, renewable energy can also offer solutions by the use of solar energy to power pumping stations that provide potable water.

4.1.4 Energy Poverty and Gender

Energy poverty is defined as a "lack of choice to adequate, reliable, affordable, efficient, safe, and environmental benign energy services to support economic and human development" (Masud *et al.*, 2007). Energy poverty contributes to continued income poverty and the poverty cycle because the percentage of income attributed to the consumption of energy services is higher for poorer individuals. Energy services include lighting, refrigeration, and its ability to power devices and machines that have consequent effects on the provision of health and education (Karekezi & Majoro, 2002). Communication and information technology are also modern energy services powered by electricity. Agriculture activities such as "water pumping for irrigation, fertilizer, mechanized tilling, and processing which increases crop yields and productivity" all require access to energy (Huang & Chen, 2005) Additionally, on a household level, domestic time-saving appliances, cooling, heating, and transportation are necessary energy services of the modern 21st century. Limited access to modern energy such as electricity hinders the provision of lighting and the ability for students to study at night or for businesses to stay open late to increase sales and therefore, has a direct relationship with education and income levels.

Energy poverty is also highly linked with gender. Women are traditionally tasked with household activities such as cooking. As previously stated, burning fuelwood to cook food creates IAP that negatively impacts health. Therefore, as women are closer to the fumes, their health is impacted the most. Furthermore, collecting and retrieving fuelwood are also tasks that are women are responsible in most traditional cultures. Cuts, wounds, and injuries can occur during these tasks. In addition, women face exposure to hazards such as extreme weather and an increased risk of sexual assaults increasing the danger of these activities. Women are often forced to bring children with them, exposing them to the same risks (Masud *et al.,* 2007). The time required for cooking and other household chores such as collecting fuelwood also impacts the ability of women to pursue income generating activities that promote independence and empowerment (Sagar, 2005). Furthermore, female educational levels are also negatively affected by traditional energy use by absenteeism due to injuries and sickness (UNDP, 2009). Absenteeism affects girls more than boys because of the above-mentioned barriers to health as well as the time needed for cooking and finding fuelwood that are in general culturally feminine tasks. In Cameroon, female absenteeism and educational attainment is significantly lower than their male counterparts. For example, the mean years of schooling for females was 4.7 while for males it was 7.6 in 2017 (UNDP, 2018). The Human Development Index for Cameroon also shows that the female labour participation is ten percent lower than males and as explained traditional energy plays a role in women's ability to perform non-household work and earn income. Table 4.1 below from Sovacool's work on energy poverty lists the practical, productive, and strategic benefits that modern services have on women.

Table 4.1: Benefits of Modern Energy Services for Women

Energy source	**Benefits**		
	Practical	**Productive**	**Strategic**
Electricity	Pumping water, reduced need to haul and carry mills for grinding, improved conditions at home through lighting	Increased possibility of activities during evening hours, refrigeration for food production and sale, power for specialized enterprises and small businesses	Safer streets, participation in evening classes, access to radio, television, and the internet
Biomass (improved cookstoves)	Improved health, less time and effort gathering fuelwood, more time for childcare	More time for productive activities, lower cost of space and process heating	Improved management of natural forests
Mechanical	Milling and grinding, transport and portering of water and crops	Increased variety of enterprises	Access to commercial, social, and political opportunities

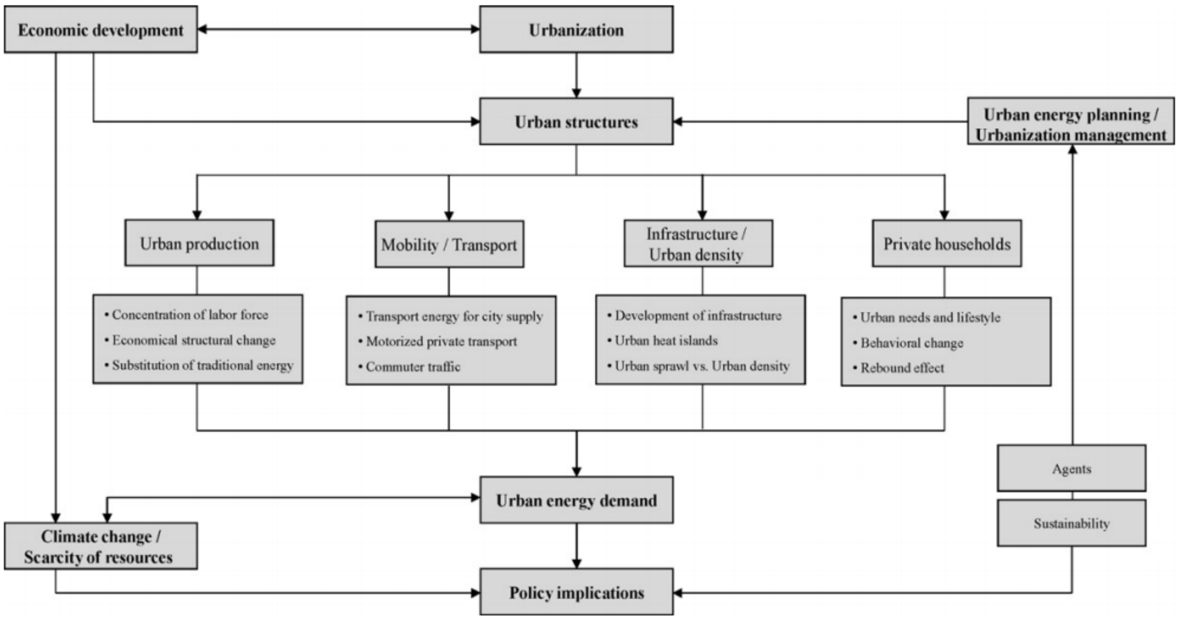
Source: Sovacool, 2012

Time-saving devices and appliances powered by electricity benefit women by improving the safety of efficiency of tasks such as grinding food and retrieving water. The provision of electricity improves the conditions at home from services such as lighting, refrigeration, and also increases the possibility of generating income through specialized small-medium enterprises (SMEs). Adequate lighting at night also improves the safety of women to travel outside in the evening by perhaps reducing the likelihood of rape. Finally, electricity can power organizations that provide social amenities for women (ESMAP, 2007) Electrical rates for these amenities that serve the public good are low in Cameroon.

4.1.5 Effects on the Urban Environment

The relationship between modern energy services and development is substantial for low income countries due to a reduction in the necessity of biomass energy sources which has detrimental effects to health and gender already discussed (Martínez & Ebenhack, 2008). There are also strong links between energy and urban development according to many authors which positively contributes to economic growth (Huang & Chen, 2005; Rutter & Keirstead, 2012; Madlener & Sunak, 2011). The main argument for this correlation is that the urban environment requires more energy than the rural hinterland as a center of economic growth, innovation, and as a hub of transportation and location of massive infrastructure investments (Madlener & Sunak, 2011). Global energy demand therefore should increase as urbanization continues as rural to urban migration leads to a concentration of people in cities as well as a structural change in the economy as agriculteralists become labourers that make goods and services. This change further requires a transition from low-intesity to high-intensity production resulting in more urban energy demand as illustraed by Figure 4.6.

Figure 4.6: Impacts of Urbanization on the Urban Energy System



Source: Madlener & Sunak, 2011

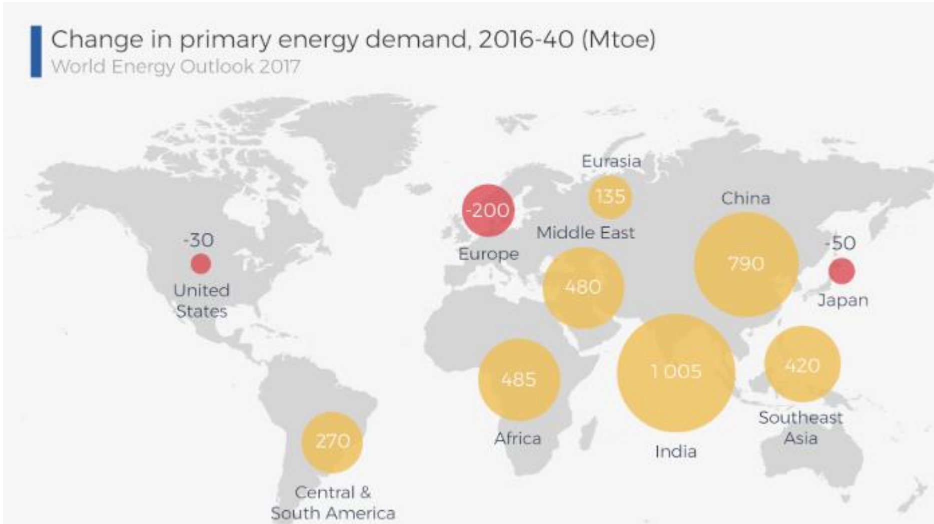
The bulidings and infrastructure required for an urban environment are also energy intensive, especially with the nessissity of heating and cooling due to seasonal changes in temperature. Energy is also nessessary for transportation and trade to move goods, services, and people in and out of urban centers. Furthermore, as fewer people are agriculturalists because urbanization results in a decreasing rural population, the farming sector becomes increasingly mechanized requiring additional energy (Huang & Chen, 2005). The process of urbanization[18] has been the global trend with 55% of the world's population living in cities and projected to hit 68% by 2050 (UN, 2018). Africa is urbanizing at a faster rate than ever before, and Cameroon is no exception with its urban population increasing from 13.94% in 1960s to 55.78% in 2017 (World Bank, 2017). Global energy demand therefore should increase as urbanization continues as rural to urban migration leads to a concentration of people in cities as well as a structural change in the economy as agriculteralists become labourers that make goods and services. This change further requires a transition from low-intesity to high-intensity production resulting in more urban energy demand

[18] Urbanization is the process of migration of people from rural agricultural areas with low population densities to cities which have larger populations and higher population densities. This process usually occurs with the proliferation of production activities and industries which results in consequent gains of economic development.

(Madlener & Sunak, 2011). The bulidings and infrastructure required for an urban environment are also energy intensive, especially with the nessissity of heating and cooling due to seasonal changes in temperature. Energy is also nessessary for transportation and trade to move goods, services, and people to and from urban centers. Furthermore, as fewer people are agriculturalists because urbanization results in a decreasing rural population, the farming sector becomes increasingly mechanized requiring additional energy (Huang & Chen, 2005).

Urban energy systems are defined as the "sectors and processes needed to satisfy the energy service demands of an urban area" (Walker, Poponi, Lefevre, 2015). The world is becoming more urban, so the future of urban energy systems will be a key determinant of meeting energy demand in ways that are sustainable (Rutter & Keirstead, 2012). Figure 4.7 illustrates that the share of primary energy demand is projected to change drastically on a regional level by the year 2040. While developed countries such as the United States, Japan, and areas of Europe will experience a decrease in energy demand, developping countries such as India, China, and parts of Africa comprise the largest share of future energy demand. This augmentation will increase the pressure of energy supply which if not met could inhibit economic growth and cause political unrest. With the population in Africa projected to double by 2050, 80% of this growth will likely occur in cities which mounts pressure on municipal governance to provide for the rising energy demands of rapid urbanization (World Economic Forum, 2018).

Figure 4.7: Projected change in Primary Energy Demand from 2016-2040 (Mtoe[19])



Source: IEA, 2017

In many developping countries the positive relationship between energy and urban development seems to be becoming increasingly unclear. Rapid urbanization is leading to urban deteriation as poor urban planning, insuffecent fiscal resources, and environmental degradation decrease urban dwellers' abilities to improve their quality of life (Nyambod, 2010). The reasons for this are while urbanization and economic develoment were in the past mutually reinforcing, urbanization is now occurring in developing countries without the equivalent economic development. Problems arise such as the phenomenon of poorly planned cities which further hinders energy efficiency. For example, unplanned cities account for conjestion because of individualized transport which negatively effects the urban environment due to emissions. Pollution causes particulate matter to form in the air which are tiny particles that over long term can cause breathing problems in humans when their concentration reaches certain levels. A 2014 study listed three cities in Cameroon; Bafoussam, Bamenda, and Yaoundé, that experience significantly higher levels of particulate matter than those recommended by the World Health Organization (Antonel & Chowdhury, 2014).

Urbanization requires space to house a rapedily expanding population which when badly planned and implemented can hinder effective energy development. For exmaple, informal settlements such as slums often lack energy infrastucture and instead rely on traditional sources of energy for

[19] Mtoe: Million tons of oil equivalent

cooking and heating which also causes health concerns such as IAP (UNDP, 2009). Illegal hookups into the eletrcical grid can result in electricty shortages which increases the costs of providing electricity and is also a safety hazard. An estimated 60% of Cameroon's urban population live in slums and informal settlements (UN-Habitat, 2014). The World Bank cites that 37.8% of the total Cameroon population lived in informal settlements in 2014. In addition, ineffective energy infrastructure direct impact economic development as a whole. The lack of proper lighting and frequent blackouts negatively effects business as it lowers foreign direct investment[20] (FDI) because of higher risks, costs, and smaller returns of doing business in Cameroon. The unreliable electricity system in Cameroon is estimated to cost the country 2% in GDP every year (Kenfack *et al.*, 2011). According to an African Infrastructure Diagnostic Report (AIDR) published by a division of the World Bank in 2011, Cameroon is facing major challenges in order to meet basic infrastructure needs including access to modern energy services which impedes development (Dominguez-Torres & Foster, 2011).

4.1.6 Inequalities and Violence

The three different types of injustices that can occur in renewable energy development projects when there is insufficient community consideration and consultation are outlined by Calzadilla and Mauger (2018). These injustices are distributional injustice, recognitional injustice, and procedural injustice (Calzadilla & Mauger, 2018). All three types of injustices have occurred in Cameroon during renewable energy development project implementation. The first type of injustice, distributional injustice occurs when the benefits and costs of RE projects are unequally distributed. An example of this is hydropower development which causes problems for local communities worldwide that negatively affected livelihoods and ecosystems that communities depend on (Farfan, Peltoniemi, Breyer, 2018). In Cameroon specifically, there has been instances reported of hydro development that has adversely impacted local communities. During the development of the Mapé Dam in North-West Cameroon, there is evidence to support that forced relocation occurred and that in the process important sites to the indigenous community living in

[20] Foreign Direct Investments (FDI) are monetary or physical investments in the form of machines or infrastructure made by a corporation or individual from an outside country to a host country in order for the former to gain profits by ownership of a portion of the host countries' assets.

the area were lost. For example, gravesites that have cultural and historic values were flooded as well as the communities' homes. In addition, the community received insufficient compensation and many people were forced to leave the community (Mbih *et al.*, 2014). Where the Mapé dam illustrates the unequal costs to hydro development on local communities, another dam development Lom Pangar shows that benefits to hydro dam development were unequally distributed. Electricity generated from the Lom Pangar dam goes primarily to an aluminum smelter, Alucam whose profits are owned by a Canadian company Alcan, not to the benefit of the local people who will continue to face blackouts and power disruption (International Rivers, 2005).

Electricity access rates are unequal in Cameroon, especially between urban and rural areas. There are also injustices resulting from corrupt practises to curb dissent in Cameroon. Government controlled police forces have on numerous occasions targeted protestors in order to preserve control. For example, students protesting the lack of electricity is universities were shot at by police resulting in three deaths in 2007. Electricity provision has also been used to control English-speaking Cameroonians who comprise 20% of the population. Amnesty International reports that during the recent federal election in 2018 there were incidents of house arrests of oppositional leaders, use of anti-riot police, as well as journalist arrest affecting free speech and freedom of the press. A targeted electricity blackout was also carried out in English speaking regions where internet and telephone communications were cut from January to April 2018 (Amnesty International, 2018).

A second type of injustice, recognitional injustice, is the disrespect for people and cultures directly impacted by the development of renewable energy projects. In Cameroon, biofuel production has resulted in recognitional injustices where project developers often use the term "wasteland" to highlight that development is occurring and give the illusion to benefits but this "waste land" may have strong value for local communities. An example of recognitional injustice in southwestern Cameroon is the case of Herakles Farms illustrated by Figure 4.9, which is a palm oil plantation under SG Sustainable Oil Cameroon (SGSOC) owned by an American corporation. The local community contested the development because agricultural land was taken away from them without proper compensation or provision of alternative means of making an income (Ndi & Batterbury, 2017). Despite this local protest which was bolstered by international actors such as

Green Peace, the development continued and as a result destroyed traditional lands of two communities living in the area in 2015. Local livelihoods were negatively impacted as land owners lost control of their traditional farm lands, and benefits to the community was limited as jobs that were promised never materialized and communities still did not have access to electricity despite the close proximity to the palm oil development. Furthermore, one local activist Nasako Besingi who protested the development have been wrongly convicted to spend three years in jail for merely exercising his democratic rights (Greenpeace, 2015). The uncertainty surrounding the development due to failed promises of providing local jobs and insufficient community consultation led to widespread distrust towards SGSOC by local communities (Ndi, 2017). There is also evidence that Herakles Farm violates national laws and international conventions because illegal logging took place in 2010 without proper authorization from the Ministry of Environment to assess the environmental, social and economic impact of the development, and local protests were met with intimidation and in some cases arbitrary arrests (Ashukem, 2016). The differences in power between large foreign companies such as Herakles Farm and local communities is that small villages lack the financial and legal capacity to take these giant firms to court and have legal compliance to protect local ownership of land (Fonjong *et al.*, 2016). The ability of these giant companies to take over large tracts of land without due consent of the local communities living on the land is defined as land grabbing. Other foreign owned companies such as Sithe Global Sustainable Oils in Cameroon has also been exposed to similar forms of injustices towards local communities due to their failure to acquire informed consent of the local population who are directly impacted by the project's development (Pemunta, 2018).

Figure 4.9: Herakles Farm

Source: Greenpeace, 2019

The final form of injustice, procedural injustice is the lack of genuine information and public participation processes during renewable energy development planning and implementation. Community consultation is important because there are environmental costs from renewable energy development as discussed previously that could negatively impact the health, safety, and local livelihoods. Regulatory measures to minimise these consequences such as Environmental Impact Assessments[21] (EIA) are often less widely regulated and enforced than developed countries. Therefore, an insufficient understanding of the consequences of renewable energy development and decisions on these trade-offs can lead to injustices in project outcomes (Calzadilla & Mauger, 2018). Procedural injustices include a failure in EIA implementation when impacts of the project on the local community are unaddressed and local concerns are ignored. A lack of community consultation and consent results in feelings of violation for stakeholders which can compound in distrust and dissent towards developers. As explained, palm oil plantation corporations such as SGSOC often fail to consult with community members to gain their perspectives and address their concerns. In addition to biofuel development, hydro dams are often planned and implemented between government officials and foreign owned companies behind closed doors without proper consultation of the local communities directly impacted. Illegal logging and deforestation also threaten communities in Cameroon such as the pygmy people by compromising traditional livelihoods such as hunting and gathering (Greenpeace, 2019).

Renewable energy development in Cameroon has had significant negative impacts on social, economic, and ecological systems. The current energy system has been ineffective in increasing access levels to modern, reliable, and safe electricity in Cameroon while mitigating the negative effects of energy development on the environment and the people that rely on traditional livelihoods. Furthermore, unequal power distributions between foreign owned conglomerates and the Cameroon government on one hand, and the communities that are disproportionately affected by renewable energy development is creating injustices, conflict, and violence further inhibiting sustainable energy development.

[21] EIAs are reports aimed to evaluate the environment, social, and economic impacts of a project prior to a final decision by authorities to (dis)approve new development. EIAs measure both the costs and benefits of the project.

4.2 Applications of Theoretical Framework in Cameroon

Research Question 2: Why are these problems occurring?

In this section each theory in the Conceptual Framework in Chapter 2; socio-technical, socio-ecology, and political ecology, will be analysed to assess which approach best explains why the problems with renewable energy development in Cameroon are occurring which are hindering sustainable renewable energy development.

4.2.1 Socio-technical Factors

As explained in previous sections, traditional biofuel energy in the form fuelwood, coal and dung are primarily used in Cameroon for cooking and heating purposes. The need to transition to more safe and efficient forms of energy to improve the well-being of woman who are severely impacted from breathing IAP is an important aspect to reduce energy poverty. Although gas is not renewable and has detrimental effects to the environment, it does provide a safer alternative for cooking energy because it results in far IAP and is more efficient than burning fuelwood. However, domestic propane gas for cooking remains very expensive for the majority of the Cameroon population with user rates at less than 50% in Yaoundé (ESMAP, 2007). Electrical connection to the national grid is also expensive because although electrical rates are 50 CFA Francs[22] per Kwh there remains substantial costs to connecting to the national grid (Eneo, 2018). Therefore, the demand for electricity and gas could be inhibited by the high initial costs of transitioning to new technology such as a gas or electric stove. End-users are often forced to borrow money or establish community partnerships in order to afford new devices. Petroleum products are also expensive because they are primarily imported from other countries, which adversely effects Cameroon's energy security (Enongene *et al.,* 2016). Tariffs on oil and gas imports further exacerbates the high costs for the poor in comparison to their wages and the cost of living. A theory of energy development called the "energy ladder" outlines that as income increases, a transition towards more modern and efficient energy sources occurs (UNDP, 2009). However, this does not seem to be the case in Cameroon, where even higher income groups continue to utilize fuelwood for cooking and heating (Hiemstra-van der Horst & Hovorka, 2008). The rationale behind this

[22] The Central CFA Franc (XAF) is the currency used in Cameroon as well as six other Central African countries.

juxtaposition could be a high-risk aversion to the costs required to transition to modern energy such as electricity. Low income and limited infrastructure are two barriers that prevent households from connecting to the electrical grid. Electricity requires a permanent structure which is built according to electrical codes. Building a new home or making changes to current home in order to support a connection to the electrical grid is very expensive and therefore, unfeasible for poorer households, especially in rural areas (Sovacool, 2012). The initial costs of electrical grid connection are expensive, requiring an electrician and materials such as wires which is expensive. In addition, a monthly electric bill is risky as income is more precarious and unknown due to other potential costs such as health care and investment in education which may overrule electrical connection to the national grid.

Other factors such as traditions, social expectations, and cultural barriers may also be responsible for hindering the modern energy transition. Culturally, Africans prefer cooking over the fire which many consider to result in food tasting better with a smoky flavor (Murphy, 2001). Another barrier that could be negatively impacting perceptions of renewable energy is that the benefits of modern energy technology may be unknown to the majority of the population. Energy literacy comprises of knowledge about energy and where it comes from, as well as recognition of alternatives such as renewables (Comeau *et al.*, 2015). A study undertaken in South Africa illustrated that the factor that was the most influential on energy literacy was proximity, and that the closer or more familiar a RE technology or project is to the respondent, the more knowledge they seemed to have of the inner mechanism and functions of how the RE technology functions (Simanauskaite, 2014). In addition to proximity, education seems to also be a factor in the domain of energy literacy according to another study that found there was a strong correlation between education on RE and energy saving behavior in students (Halder *et al.*, 2010). Perceptions in renewable energy development are can also be shaped by the levels of trust towards project developers and decision makers from the local community. A survey from a Canadian study illustrated that Aboriginal Canadians were more distrustful in the information from the public and private sources than non-Aboriginal Canadians which could be due to their historical mistreatment by government authorities (Moore et al, 2014).

The reasons for the poor implementation of transitioning to more modern energy for cooking in Cameroon could be the high initial price of changing technology for gas and electricity as well as a government and private partnership failure in providing reliable and affordable gas and electricity access. All these factors keep the price high and demand low for propane gas and electricity so that the transition does not occur. The supply of energy services in Cameroon is also a barrier to effective energy transitions. Private enterprises are not effectively providing energy access because of a lack of competition. The stockage and replenishment of propane tanks/bottles seems to be a key issue which increases the risk and lowers the cost-savings and availability of gas as a cooking energy source (ESMAP, 2007). In addition, there are high risks to entering the market as security is required to protect gas depot centers from theft. Market failures[23] can also result from the formation of monopolies that can afford to keep prices artificially high in order to maximize profits because they are the sole provider of the good or service. In Cameroon the CSPH is solely responsible for stabilizing the price of gas, and therefore, there is a disincentive to lower the price and in turn their profits by increasing the supply and availability of gas. In addition, the formation of a monopoly can also been seen in the electrical sector of Cameroon as Eneo is the sole provider of electricity, therefore, there is a disincentive to lower prices or provide electricity for rural areas. This increases the likelihood of the phenomenon of "uneven-electrification" to occur where electric monopolies prefer to serve urban centers rather than rural areas because potential users and profits were more assured (Cook & Bank, 2005). Connection to the electrical grid in remote areas is more costly and poorer populations lack the ability to pay service and connection fees. Therefore, the private sector is often unwilling to supply electricity to rural areas with lower population densities and poorer populations who lack sufficient income or access to credit to pay for electricity. This phenomenon can be seen in Cameroon with rural electrification access at rates far lower than urban areas.

Given the low purchasing power of the population in developing countries such as Cameroon and the economic constraints that hinders RE development, renewable energy requires an enabling environment for its promotion in the form of government policies and regulation. Socio-technical theories offer explanations for poor access rates to modern and affordable energy, but this theory

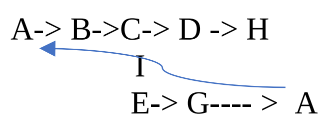
[23] Market failures are situations where inefficiencies in the allocation of resources made by the free market results in a loss to societal well-being.

offers limited rationale for other components of sustainable energy which includes renewable energy development effects on the environment and the local communities who depend on traditional livelihoods and how these factors are mitigated. These considerations are important because they impact the abilities of future generations to meet their energy needs which is an essential component of sustainable energy development.

4.2.2 Socio-ecological Perspective

Social–ecological systems are complex “integrated systems in which humans are part of nature and therefore cultural, political, social, economic, ecological and technological components interact (Hodbod & Adger, 2014)”. The theory of socio-ecology argues that socio-ecological systems are always in a state of change because of the interacting relationships between actors that cause feedback loops due to direct and indirect changes in one factor that causes change in another which when drastic can alter the entire system. For example, Figure 4.10 shows that factor A influenced factor B, which in turn effected C, which caused changes in both factor C and factor E. Factor E caused a change in G which resulted in a feedback loop where the original factor A is impacted which results in the entire system changing yet again. Unlike socio-technical systems a perfect equilibrium can never be maintained as feedback loops occur between actors and over time with sufficient pressure, the system eventually crosses thresholds that result in regime shifts that could be irreversible and disastrous. To mitigate these constant changes in a sustainable way there are three principles of social–ecological systems to reduce vulnerabilities which are; resilience (ability to absorb shocks and disturbances), adaptation, and capacity building (Levin *et al.*, 2013).

Figure 4.10: Feedback Loop Illustration



Source: Own Illustration, 2019

Anthropogenic climate change increases the necessity for humans to notice and respond to rapid ecological change in order to adapt affectively. For example, understanding weather patterns and behavior changes in animal species. In practise there is robust evidence that integration of local traditional knowledge (LTK) with additional scientific and technical knowledge can improve disaster risk reduction and climate change adaptation (van Aalst, Cannon, Burton, 2008). Both of which improve the sustainability and resilience of communities and their livelihoods. Examples of this include indigenous knowledge of early warning signs of a disaster that saves lives by people evacuating the area. It has also been argued that LTK has been underutilized in the development field, and that this oversight can have serious repercussions on the successful implementation of development projects (Taylor & de Loë, 2012; Berkes, 2009; Blaikie *et al.,* 1997; Agrawal, 1995). Although ties between RE development and LTK have not been previously defined, LTK does have practical applications in other fields related to RE, including, resource management, urban development, and sustainable economic development. All of these different constructs also relate to RE because it is a natural resource that is a fundamental component of the modern built environment[24]. A study undertaken in Buea Cameroon that focused on water supply and the effect that urbanization had on community management scheme showed the complexity of responding to social-ecological change. The researchers found that with urbanization comes increasing complications in effective management and institution building largely as a result of a rapidly expanding heterogenous population. Namely that the myriad of people in the growing community were not well represented, especially the "outsiders" coming into the community and this caused internal conflicts that stalled the project (Sally *et al.,* 2014). A further study in another African county Ghana illustrated that communities that were homogenous were more effective to locally manage water and sanitation services in rural environments than communities that were "ethnically diverse" (Sun, Asante, Birner, 2010). Urban environments are more complex and therefore acquiring united consent and ensuring that all of an urban communities' diverging needs and concerns are met proves very difficult.

Many authors argue that LTK is instrumental in sound resource management practises (Baird, 2007; Taylor & de Loe, 2012; Clark & Brake, 2009). As resources become scarcer it becomes

[24] The built environment refers to the homes, buildings, and other types of infrastructure that humans have created to live, work, and do leisure activities vastly altering the natural landscape.

more important to manage these resources wisely. Baird (2007) asserts that Community Based Co-Management (CBC) is instrumental to addressing problems of a socio-ecological nature. In his paper he explains how the Local Ecological Knowledge (LEK) of the people living near the Mekong River in Southern Laos solved the tragedy of the commons taking place. The fisheries were being depleted as no one owns the fish, and therefore the livelihoods of fisherman were at risk. Using their LEK to monitor and adapt to this problem, the CBC framework was successful in allowing for decision making processes that created "regulations to meet local conditions (Baird, 2007, 87)" which meant that the community respected and abided by them. In this way the fish stocks and the likelihoods of the fisherman were saved. In Cameroon, during the development of the Mapé dam, the local community noticed that the local fish stocks were negatively impacted (International Rivers, 2005). Another rationale behind the LTK approach to resource management is that the people on the land have the most knowledge about their resources and have the most to lose if these resources are not managed sustainably. In multiple cases integrating scientific and local knowledge together in resource planning resulted in positive outcomes where knowledge was improved in a general sense and innovation into ways to protect valuable resources was generated (Clark & Brake, 2009; Giordano *et al.*, 2010; Kroon, Robinson, Dale, 2009).

LTK is also applicable to sustainable urban development as well because of its ability to improve the knowledge base of urban planning which increases the health, safety, and wellbeing of urban inhabitants. For example, Corburn (2003) details how "environmental problem solving" that is linked to behaviors and the local environment has begun to be met with success in some cities in the United States, and its implementation in the developing world could have drastic benefits to global health. His examples of how missed information could have led to an air toxicity problem which otherwise would have become a dangerous health hazard in the community shows the validity of LTK in the urban context (Corburn, 2003). Another study shows how Local Ecological Knowledge (LEK) similar to LTK "can complement ecological research information and indicate objects and places important to stakeholders (Yli-Pelkonen & Kohl, 2005). This information is beneficial because urban planners can then preserve spaces of communal importance which protects the uniqueness of the locality by benefiting the positive psyche of citizens. Proper urban planning should take into consideration local knowledge and even traditional knowledge as it allows for specific contexts to be recognized and respected, ensures that there is proper public engagement and support, and finally brings to attention crucial information that has the tendency to be overlooked by the "professionals." This evidence supports that LTK can improve the knowledge base of both lay people and the professionals for "joint fact-finding" to occur (Mallett, 2007).

Indigenous knowledge systems were also recognized to benefit the sustainability of projects in a rural study of a water provision project performed in Cameroon where the participants' local knowledge informed the projects' design and implementation (Fonjong, Emmanuel, Fonchingong, 2005). Another study also performed in Cameroon illustrated the consequences of insufficient community engagement in a water project which impeded the projects' effectiveness. A failure on behalf of the developmental project's authorities to effectively take under consideration the population's local knowledge resulted in a lack of holistic understanding of the unique local needs and conditions that were implicated. Furthermore, the sustainability of the project was jeopardized because social results such as capacity building were seen as less important than the physical outputs of the project. Failing to focus on the community's strengths and insufficiently addressing their weaknesses, the resilience of the community was largely unimproved according to one research. The same researcher argued that the larger objectives of developmental projects such as poverty reduction, community participation and institution building could have been better attained if local traditional knowledge was considered and better integrated during the projects' implementation (Njoh, 2003). Additional benefits of community participation include local empowerment, democratic promotion as more voices are being heard, low cost solutions that receive more support, and promotion of justice, especially of the poor by addressing local needs (Corburn, 2003).

As previously illustrated in Section 4.1, food and water security are serious issues threatening health and exacerbating energy poverty in Cameroon. LTK could enhance the transition to modern cooking technologies and involvement of local decision-making in co-management of water sheds and forests could result in improved knowledge sharing on resources which could improve sustainable energy development. In the realms of sustainable development, LTK can "benefit cooperation, stakeholder participation, understanding the long-term effects of project development and recognition of inter-generational equity and justice, as well as moderate production and consumption habits" (Eyong, 2007). Additionally, LTK has the potential to foster more socially egalitarian and environmentally sustainable relationships between human societies and nature (Ellis, 2005). Furthermore, sustainable farming practises that incorporate technology and innovation with the local knowledge systems may increase local capacity to enhance food security and reduce adverse effects to the environment. However, power relations may hinder the ability of local communities to participate in socio-ecological systems which creates injustices and has consequences for sustainable energy development.

4.3.3 Political Ecology & Power

Conventional energy development refers to top-down governance of the state for implementing electrical provision from non-renewable energy sources such as oil and gas. However, according to some authors there is a disconnect between how conventional energy systems have been organized and how end-users make decisions on household energy consumption. In the United Kingdom top-down energy policy has not resulted in desired changes in energy efficiency behaviors of the population. One research team argues that citizens do not require access to information to make informed decisions but require "community knowledge networks" where recognition of local contextual knowledge is recognized and promoted. The authors highlight the different between information and knowledge and argues that energy usage must be contextualised in how individuals actually use energy in their households. The found that community approaches increase participation, engagement, trust (Catney et al., 2013). Top down energy development is ineffective for numerous reasons. Governments should regulate the energy sector to curtail corruption as well as implement policy to make energy transitions more feasible. However, government officials are often occupied with other sectors that generate government revenue and also lack sufficient funding and effective coordination across ministries to promote renewable electricity development, especially in rural areas. Strong governance and effective institutions are lacking in Cameroon as well as other parts of the developing world due to high levels of corruption. Another study found that the Mexican public was largely uninformed about RE technology and that there was inadequate communication between sectors of society such as the government, universities, and private enterprises that hindered the development of renewable energy development (Mallett, 2007).

International NGOs that promote top-down energy development are often poor at increasing capacity building of the community to manage and maintain renewable energy project technology which has led to unsuccessful projects in the long term. A main factor behind this tendency is the traditional view of North-South relations which argues that a technology transfer should occur from the developed world to the developing world. The technology transfer between North and South is criticized by Mallett (2007) who instead promotes a "technology cooperation" model that comprises of energy literacy and energy citizenship where participants play an active role in renewable energy development (Mallett, 2007). Energy literacy has been discussed previously in the socio-technical section. Energy citizenship involves public engagement on energy issues as well as increased local production and management of energy sources *(*Comeau *et al.*, 2015) This concept is closely related to energy literacy because knowledge can encourage engagement with renewable energy, and reversely engagement with RE incentivizes gaining more knowledge on energy development and its impacts on communities. Until recently, energy development assistance from developed countries was primarily focused on technology transfer and fixed capital assets such as infrastructure, with less consideration on improving self-sufficiency and local capacity building. The majority of development assistance concentrated on pilot projects experiments instead of a genuine interest in diffusing the knowledge or technology to local organizations or communities. The reasons for the concentration on technology transfer could stem from the donor's self-interest to sell their own technology or build markets for export rather than a true concern for the poor (Martinot, 2001). Additionally, another criticism is that a sole focus on expanding electrical supply does not solve the issues of affordability or increase the choices of energy services for poor and rural populations (Gaye, 2007).

Injustices mentioned in section 4.1 which include; recognitional, distributional, and procedural injustices all seem to encompass problems such as unequal power distributions and unfair trade-offs of the political ecology framework. A failure to recognize communities' LTK by not adequately consulting with local communities directly impacted by energy development projects has caused problems in other developing countries such as Mexico. One researcher found that limited information resulted in a "lack of engagement with those developing, producing, and selling the technology" so that the consequence was that perceptions grew that the technology was flawed, and so, the public become negatively informed about the RE technology (Mallett, 2007). Mallett (2007) argues that the incorporation of LTK can lead to more empowerment of the local people to address local problems and solve them using their own knowledge and skills which strengthens democracy as the voices and concerns of the people are heard. Also, LTK was effective in that community planning resulted in low cost solutions that people followed and took part in. Lastly, justice can also be promoted by the inclusion of the community in order to better redistribute the benefits and costs of renewable energy development. The last impact, justice is especially relevant for renewable energy as the local people could gain control over the energy resources located on their territory and can profit from its use (Corburn, 2003).

Recently, community-based renewable energy or community-owned renewable energy are types of adaptive governance approaches where local communities produce their own energy through co-operative structures and gain the benefits from its use. Numerous community-based renewable energy projects have been successful in many parts of the developing world. Cooperative approaches, whereby local civil society organizations partner with governmental bodies as well as NGOs to install RE technologies have been shown to increase engagement and capacity building of local people. This is already being accomplished in several communities in Africa (Munro *et al.,* 2016; Ahlborg, 2015). Community solar and other renewable projects produce energy that is locally owned, so this could bypass corruption and corporate profits, as well as having the benefit of communal use. This energy independence could be a way to empower the people, increasing their energy literacy as well as their energy citizenship.

Co-management of resources between government and locals is also promoted by Taylor & de Loe (2012) in their study where they argued that groundwater supplies were improved when the LTK of the people living in a dry region of South Australia was accepted. They argue that collaboration is important because it "raises legitimacy and credibility, lowers disputes, is context specific, links knowledge to action, results in joint fact finding, and is a tool for empowerment (Taylor & Loe, 2012)." Another rationale behind adaptive management is that the people on the land have the most knowledge about their resources and have the most to lose if these resources are not managed sustainably. In multiple cases integrating scientific and local knowledge together in resource planning resulted in positive outcomes where knowledge was improved in a general sense and innovation into ways to protect valuable resources was generated (Clark & Brake, 2009;

Giordano *et al.*, 2010; Kroon, Robinson, Dale, 2009). Accruing the support and participation of people on the land is fundamental in order for day-to-day use of resources to be extracted, used, and managed in a way that is sustainable that benefits the people and protects the resource for future use. Managing and sharing the wealth of resources with indigenous communities also aid in the economic development of these communities, so they have the resources to solve their own developmental problems.

Each of the three systems theories offer different rationales for which factors are the most influential to promote sustainable energy development. For socio-technical systems the improvement of electricity access rates is possible with market factors of demand and supply. According to this theory, raising incentives to transition to cleaner technologies by decreasing prices and risks will better permit households to afford to connect to the electrical grid or use propane gas. Furthermore, creating a competitive market to enable new small businesses to enter and promote innovation and investment would improve the ability of the energy market to supply affordable and accessible renewable energy to the population. Finally, promoting energy literacy and skill training of renewable energy technologies and other cleaner and safer cooking energy devices such as improved cook stoves could decrease detrimental health impacts due to IAP. Socioecological systems theories argue that sustainable energy development should encompass effects to the environment and ecological services that life depends on such as air, water, and soil quality that have consequent repercussions of human health and livelihoods. Local knowledge systems such as LTK should be integrated into the implementation of sustainable energy development in order to improve knowledge sharing between professionals and the communities that are more capable of witnessing ecological changes on a local level according to this theory. In order to adapt to changes and adopt sustainable livelihoods local communities need to protect agricultural production and other traditional activities such as fishing. However, as illustrated by the case studies on hydro development which has negatively affected fish stocks, and biofuel production activities such as illegal logging that further exacerbate environmental phenomena such as deforestation, desertification, and salinization improvement should occur to better recognize and protect ecological systems.

Political ecology frameworks demonstrate that injustices are occurring as a result of a renewable energy development in Cameroon. Recognitional injustices seem to be occurring as a result of land grabbing from agrobusinesses and hydro dam development has resulted in flooding that has negatively impacted communities' homes and places of cultural importance such as grave sites. Distributional injustices between the actors that benefit and which actors endure a disproportionate share of the costs of renewable energy development seem to also be occurring in Cameroon with local communities receiving little economic gains from renewable energy development. Additionally, there is unequal distribution of electricity between the rural periphery and urban centers and local communities that are in close proximity to renewable energy projects often lack access to electricity that large foreign-owned companies enjoy such as Alucam. Finally, procedural injustices such as a lack of community consent and failure to implement EIAs seems to have resulted in mistrust and protest towards renewable energy development, especially in the case of Herakles Farm in Cameroon. Therefore, all three theories; socio-technical, socioecological, and political ecology explain some aspect for why the problems with renewable energy development in Cameroon is occurring. Socio-technical market factors can explain the low access rates to electricity due to insufficient electricity supply and inability of consumers to afford the transition to electricity on a household level. Environmental problems and the consequent repercussions to food and water security and its impacts on human health can be explained by insufficient attention to socio-ecological systems in Cameroon. Lastly, political ecology theories convey the problems affecting energy injustices in Cameroon due to power differentials between powerful corporations and elites and small local communities. In order to comprehensively understand the range of factors, actors, as well as the relationships between them inhibit sustainable energy development in Cameroon, all three theories inform the discourse on renewable energy development and each offers solutions to better promote sustainable energy development in the future.

Chapter 5

Conclusion

5.1 Summary of the Study

The results of this study suggest that Cameroon faces significant problems in the realm of renewable energy development. Inadequate access to modern energy services such as electricity remains an issue that effects economic and socio-economic growth and hinders continued sustainable development in Cameroon. Furthermore, a heavy reliance on traditional energy such as fuel-wood for cooking energy causes negative environmental and health impacts which result in consequences for food and water security. Traditional energy use is also a gender issue as it decreases the ability for women to participate in revenue generating activities, and health problems are caused by breathing in IAP and retrieving fuelwood. In addition, ineffective and inequitable energy systems compound problems such as the deterioration of the urban environment, and lead to injustices between the center and periphery in terms of the distribution of benefits and costs of renewable energy development between the rich and poor.

An analysis of the three different systems in the theoretical framework gives evidence that each theory plays a role in describing the reasons why these problems in Cameroon's renewable energy development are occurring. Socio-technical systems seem to illustrate how individuals make decisions on energy source choices based on not only the cost of new technologies, but also the risk factors involved. This theory also perhaps explains why private and public actors are ineffective in improving rural electricity access rates because of monopolies that are disinterested in serving poor in remote rural areas, and a lack of financial and administrative government abilities. The socio-ecological rationale could be utilized to explain how complex systems require local traditional knowledge and understanding of unique contexts in order to recognize feedback loops and avoid thresholds and regime shifts. Resilience and capacity building are necessary for adapting to abrupt ecological change in order to sustain livelihoods which might not be adequately supported in Cameroon. Renewable energy development in Cameroon should therefore increase engagement and community consultation in order to avoid severe environmental consequences and unacceptable impacts to local communities' well-being. The final theory, political ecology, adds the importance of power differentials that create inequalities of the benefits and costs of energy development and other forms of injustices that negatively impact sustainable energy development.

5.2 Recommendations

The evidence provided points to the conclusion that the consequences of renewable energy development in Cameroon are caused by integrated factors that affect social, economic, technical, and ecological systems, a concerted approach is therefore recommended to address the problems on a local, regional, and national level. Community, public, private, and international actors and organizations must work together in order to improve renewable energy development in Cameroon to result in a more sustainable and resilient energy sector. Informing decision makers on more effective policies to improve renewable energy development will allow a better mitigation of the negative impacts caused by renewable energy projects in developing countries like Cameroon while increasing access to modern, reliable, and affordable energy services. With this in mind, sustainable energy development is not a fixed destination, but a dynamic evolving process that requires continued learning, adaptation, and cooperation in order to accommodate subjective perspectives on what constitutes as sustainable energy development.

The following recommendations are proposed to mitigate the problems with renewable energy development in Cameroon.

1. Increase the affordability of electricity and gas in order to improve the choice and availability of alternative cooking technologies as well as other energy services such as lighting, cooling, heating, and the ability to power machinery and information technology devices that create opportunities for the creation of entrepreneurial activities.
2. Provide microloans to communities or small-medium enterprises to invest in new technology such as solar panels which can also be used for the dissemination of solar ovens and improved cooking stoves to reduce the consequences of IAP and deforestation on human health and the environment.

3. Develop a solar energy market to take advantage of the vast solar energy potential in Cameroon by providing a favorable business environment through subsides for investment and new entrants in the market, limiting the opportunities of monopoly creation in order to preserve competitiveness, lower prices, and result in more decentralized energy systems that are more accessible to rural areas and increases national energy security.
4. Improve community consultation and consent possesses to increase information sharing between local actors and decision makers, and mitigate the negative ecological impacts of renewable energy development which often compound into consequences for human health and local livelihoods resulting a net loss of well-being.
5. Fairly compensate communities that are negatively impacted by hydro and biofuel energy development. Co-develop and finance alternative livelihoods strategies and increase capacity building by training and education investments to improve local resiliency to ecological change.
6. Regulate and enforce laws on illegal logging and other detrimental renewable energy development practices such as agricultural pollutants from biodiesel plantations to better preserve forests and river, lake, and groundwater aquifers in order to reduce food and water insecurity.
7. Raise levels of awareness and education of renewable energy development by offering training on solar energy technology maintenance and aid in the dissemination of mini-hydro stations for community use and management.
8. Cooperate with international organizations, improve governmental integration, and create partnerships with NGOs to increase opportunities for innovation and synergies across private and public sectors.
9. Enhance opportunities for co-management of resources such as forests and adaptive governance frameworks to improve decision making and reduce injustices resulting from inequitable distributions of the benefits and costs of renewable energy development.
10. Invest in opportunities for women and other disfranchised factions of the population in the periphery to improve power differentials between the have and have nots.
11. Create new rural energy infrastructure and improve electrical access to social amenities such as health, education, and centers that focus on women empowerment.

12. Foster relationships and encourage learning to broaden participation in renewable energy development in order to promote energy literacy and energy citizenship among the population of Cameroon.

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Chapter 1 & 2

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