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ANALYSIS OF ETHIOPIAN ENERGY SYSTEM TRANSITION TOWARDS RENEWABLE ENERGY SECTOR EXPANSION

Master Thesis Presented By

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List of Acronyms and Abbreviations

PE	:	Primary Energy
SE	:	Secondary Energy
EG	:	Electricity Generation
TPES	:	Total Primary Energy Supply
MLP	:	Multi Level Perspective
NRT	:	Niche Regime Theory
GoE	:	Government of Ethiopia
kW	:	Kilowatt
kWh	:	Kilowatt/hour
MW	:	Megawatt
MWh	:	Megawatt/hour
GW	:	Gigawatt
GWh	:	Gigawatt/hour
TW	:	Terawatt
TWh	:	Terawatt/hour
CO2	:	Carbon Dioxide
GDP	:	Gross Domestic Product
GTP	:	Growth and Transformation Plan
HDI	:	Human Development Index
LED	:	Light Emitting Diodes
NGO	:	Nongovernmental Organization
PPA	:	Power Purchasing Agreement
IPCC	:	Intergovernmental Panel on Climate Change
HPP	:	Hydropower Plant
SDGs	:	Sustainable Development Goals
EEA	:	Ethiopian Energy Authority
EEP	:	Ethiopian Electric Power
EEU	:	Ethiopian Electric Utility
INDC	:	Intended Nationally Determined Contribution
NDC	:	Nationally Determined Contribution
UNDP	:	United Nations Development Programme
SEforALL	:	Sustainable Energy for All
WB	:	World Bank
EEPCo	:	Ethiopian Electric Power Corporation
GIZ	:	Deutsche Gesellschaft für Internationale Zusammenarbeit
GHG	:	Greenhouse Gas
EU	:	European Union
EEA	:	Ethiopian Electric Agency
EnDev	:	Energizing Development
MoWIE	:	Ministry of Water, Irrigation and Electricity

IAP	:	Indoor Air Pollution
PJ	:	Petajoules
ICS	:	Inter-Connected Systems
SCS	:	Self-Contained Systems
USD	:	United States Dollars
ADLI	:	Agricultural Development Led Industrialisation
LPG	:	Liquified Petroleum Gas
WBISPP	:	Woody Biomass Inventory and Strategic Planning Project
BLT	:	Branches, Leaves, and Twigs
BAU	:	Business-as-usual
GERD	:	Grand Ethiopian Renaissance Dam
IMF	:	International Monetary Fund
UNICEF	:	United Nations International Children's Emergency Fund
DFID	:	Department for International Development
USAID	:	United States Agency for International Development
GPE	:	Global Partnership for Education
CFL	:	Compact Fluorescent Lamps
SNNPR	:	Southern Nations, Nationalities, and Peoples' Region
JICA	:	Japan International Cooperation Agency
NBPE	:	National Biogas Program of Ethiopia
EUEI PDF	:	EU Energy Initiative Partnership Dialogue Facility
SSA	:	Sub-Saharan Africa

Abstract

The ‘Energy Crisis’ has become the talk of the town in pretty much every developing and lower developing countries in today’s world. It is characterized by a state where the country’s locally available energy resources are being depleted and it is dependent on imported fuel. The problem is considered as although not parallel, but a descendant of the food crisis in terms of the seriousness of the problems in developing nations essentially in Sub-Saharan Africa (SSA). Ethiopia is one such country which nevertheless going through a rapid scale of development (nearly 11 % annual growth rate as of 2017 according to the World Bank) and also is endowed with an enormous amount of natural resources such as hydro, wind, solar, geothermal energy potential. The Ethiopian power sector is heavily dependent on the country’s hydropower resources. However, it needs to diversify its energy sector and integrate new and other renewable energy sources because, in the longer term, its extreme hydropower dependence may put its power sector vulnerable to natural risks like droughts which are very likely scenarios due to the climate change. Since the lack of access to modern forms of energy services left no choice for the Ethiopians than to continue their traditional biomass use, and it results in unsustainable environmental harm with deforestation, soil erosion, and many others. To address this issue, Ethiopia is taking necessary steps towards climate-friendly industrialization of the economy.

In order to understand this transition, a socio-technical analysis of Ethiopian ambitious transformation from an agrarian society to a climate resilient green society has been presented in this paper. An analytical framework will be formulated as a prerequisite for the study by introducing the theory of Multilevel Perspective (MLP). This theory enables the understanding of three different levels of socio-technical environment namely niches, regime, and landscape in which the respective actors interact with each other to facilitate the process of transition. As a part of laying the groundwork, this thorough analysis constitutes all the country’s energy-related activities and associated energy demands, conversion technologies, current fuel mix, primary energy resources, and energy policies in the Ethiopian energy system. The LEAP analysis results from Mr. Md Alam Mondal and group are summarized to obtain an understanding of the country’s total energy demand scenarios.

Consequently, the actors from each socio-technical level have been identified in the context of Ethiopia and their dynamics of interaction have been explained in order to understand the process of energy system transition of Ethiopia in the direction of diversification of its energy system and hence result in the expansion of new renewable energy sector. Most importantly the assessment suggests that the transition process is majorly driven by top-down forces and intra-level reconfiguration of regime actors. There are no bottom-up forces acting as only a little research and development work takes place in the country to develop new radical changes/technological niches. A developing country like Ethiopia has undoubtedly a bright future ahead with all systems in place and the nature-gifted natural resource potential. The ambitious goals set by the country and the international help from developed allies are definitely working in tandem to ensure their accomplishment. With its guiding vision towards development and the global climate change movement, Ethiopia surely has the potential to lead by example.

Chapter 1: Background of the thesis

1.1. Introduction

The hunger for more energy has taken the world into situations like never before. With the never stopping demand of energy to maintain and progress in the kind of lifestyle, the world has acquired. With this over-usage of fossil fuels, one could probably not deny the fact that conventional sources of energies cost us the environment and the whole idea of sustainability. There has been an inclination towards clean and renewable sources of energies since past few decades. Ethiopia is one such developing country which is taking strides towards becoming a low carbon economy. Nevertheless, it is quite an ambitious goal but the Government of Ethiopia (GoE), in past years has shown its commitment and made its position clear. However, the vital questions on how Ethiopia is going to undertake this difficult climate journey remain. What does the current status quo indicate for the energy sector in the future? What will be the challenges and opportunities on the way towards becoming a green economy? All in all, the energy system transition of Ethiopia will be analyzed with the help of socio-technical analysis.

The mother earth has provided the world with ample resources to meet the demands of humankind and other species and sustain their livelihood. However, the huge growth in the demand and consumption has led to accelerated rates of production and thereby resulting in a huge amount of waste generation. So much so that it exceeds the ability of the planet to consume it over the time (Semuels 2015). It's not the end there, instead, it gives birth to further problems like pollution (of all kinds), damage to the environment, health problems and the list goes on. Climate change, on the other hand, poses a great threat towards the whole idea of having a sustainable future (Schenker 2018). In 1896, Arrhenius in his research paper "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground", first mentioned and demonstrated of the greenhouse effect mechanism and suggested the scientific structure for the emission reduction which till date are the main topics of discussion/agenda in any climate conferences or high-level meetings in this field both nationally and internationally. (Spencer Weart 2018)

The approach towards sustainable development was the big question in front of the world. The first thing to have been noticed was the conventional energies sources which were and still are the major actors harming the environment. New and renewable sources such as wind, solar, hydro, biomass, and other novel yet clean sources have shown potential to substitute dirty fossil fuel-based energy systems. This calls for the 'Transition' of the energy systems worldwide towards renewables.

The same holds for Ethiopia, a developing nation situated in the horn of Africa. Ethiopia being one of the very important countries in the African continent, has the potential to lead by example in the field of energy transition. A country well-endowed with natural resources, if tapped, can suffice the huge energy demand in the country. It is a country of over 102 million people and despite having enormous renewable energy potential, a very small proportion of population enjoys the modern forms of energy, electricity as a common example. (Worldmark Encyclopedia of Nations 2007) Having realized the importance of clean and renewable energy resources for country's overall growth and sustainability, the government is investing on large hydropower projects and encouraging the integration of new renewable resources such as wind, solar and geothermal in its energy sector. (Mondal et al. 2017)

Many theories have been formulated to study and assess the technological transition at big scale in various fields like the history of science, technology studies, and evolutionary economics. How new technologies will be developed and/or co-exist with the former ones before phasing them out can be studied using such theories. One of the leading ones has been chosen to be this paper's primary analysis tool i.e. 'Multi-Level Perspective' developed by Dutch researcher Prof. Frank W. Geels to be used as a heuristic model to understand these transitions in a socio-technical setting. It revolves around three analytical levels namely socio-technical landscape, socio-technical regime, and novel niches. These three domains are at different levels (macro, meso, and micro) respectively and a transition is said to have taken place when the shifts occur at the meso-level socio-technical regime. Parameters like internal issues and influence from the landscape create room for niches to a breakthrough in the socio-technical regime and sometimes replace the existing regime actors. (Geels 2010)

1.2. Defining the area of research

In the last couple of years, increasing attention has been paid to emissions reduction requirements at the international, national, and regional level, with an objective of remaining well below the 2 °C average atmospheric temperature increase as decided during the Paris Agreement. (UNFCCC 2015) Many international and national organizations have released publications on this topic for developing regions of the world. Evidently, Africa holds a special place among these developing regions, notably in Sub-Saharan Africa. Even though it is unprecedently rich in terms of availability of energy resources, it is poor in energy supply, (IEA and IRENA 2018) According to the International Energy Agency (IEA), "*Making reliable and affordable energy widely available is critical to the development of the [Sub-Saharan] region that accounts for 13% of the world's population, but only 4 % of its energy demand*". (IEA and IRENA 2018)

Figure 1: Ethiopia on the map, Source: (Premium Times 2016)

In 2015, the Paris Agreement accord at COP 21 called for all countries to commit to the execution of major greenhouse gas (GHG) emission reduction. Ethiopia (see fig. 1) is also one such country which envisions to be a front-runner for this global cause among its counterparts. Rapid economic growth since last decade has led transformations on both livelihood and sectorial levels throughout the country, including increasing urbanization and industrialization rates. (Mondal et al. 2017)

Ethiopia's ambitions are particularly significant under its Nationally Determined Contribution (NDC), as it intends to reduce its projected business-as-usual (BAU) emissions of 400 $MtCO_2e$ in 2030 by 64%, implying a decrease of 255 $MtCO_2e$ down to 145 $MtCO_2e$. (Redda 2015) Along with many other countries, Ethiopia is also experiencing the effects of climate change like variations in rainfall patterns and rising average temperatures. However, the situation also provides an opportunity to adjust to a new and sustainable development model. The Government has, therefore, begun the Climate-Resilient Green Economy (CRGE) initiative to prevent the detrimental impacts of climate change and to develop a green economy with an ambition of reaching middle-income status by 2025. (USAID 2018b)

Ethiopia has enormous potentials in low-carbon energy options like solar, wind and geothermal resources, and the economic potential of the hydropower has been highly recognized in the country since decades. Ethiopia has ambitious plans to explore and exploit its large hydropower potential aiming to support its economic growth and associated energy needs. Hydropower in the country allows energy accessibility, agricultural activities, poverty alleviation and improves country's economic growth. At the same time, it avoids the massive emissions of GHGs, particularly CO2. (van der Zwaan et al. 2018) However, seasonal changes like droughts and impacts associated with climate change pose a grave threat to the hydropower potential which calls for diversification of energy mix. Therefore, Ethiopia has been chosen by the author as the area of research.

1.3. Objectives of this paper

This dissertation works around the hypothesis 'renewable energy sector expansion is possible in Ethiopian energy system'. The idea is to assess the energy system mix in the country and find out if a transition towards renewable energies can be facilitated under all current circumstances. Ethiopia has historically focused largely on hydropower resources for electricity generation and mostly dependent on traditional biomass resources to meet its overall energy demands like cooking, baking, heating. However, now the government wishes to diversify its generation mix by integrating other renewable sources to increase climate resilience as well as Ethiopia is among the most ambitious signatories to the Paris Agreement on climate change, committing to cut carbon emissions by 64% by the year 2030. (Redda 2015)

The national government is showing positive signs towards rendering full-fledged development services in order to undertake a transition from an agrarian economy to agriculture led industrial nation. Therefore, the author of this dissertation would like to analyse this transition with the help of socio-technical transition theory namely Multi-Level Perspective (MLP).

The author wishes to specify the energy system transition characteristics prior to the introduction of MLP theory to define the actors and parameters responsible for the transition to occur. Introduction of the MLP along with its interactions with the aforementioned stakeholders will work as the analytical framework for this study. The author will put forward his own interpretation of socio-technical analysis and succeeding contents of the dissertation to culminate chapter 2.

Chapter 3 will be the most important chapter as the objective is to cover the country profile, available energy practices in Ethiopia, current power sector mix, energy demand scenarios including current business-as-usual scenario and three different cases under alternative scenario, and policies.

This chapter aims to provide a firm base for the upcoming chapter as the identification of all the stakeholders directly and indirectly related to the energy sector will be identified and their roles will be presented. Finally, in chapter 4, the author wishes to carry out the interpretation of energy transition through the socio-technical lens of MLP theory according to the analytical framework set in chapter 2 followed by the conclusions and recommendation in the last chapter. (see fig. 2)

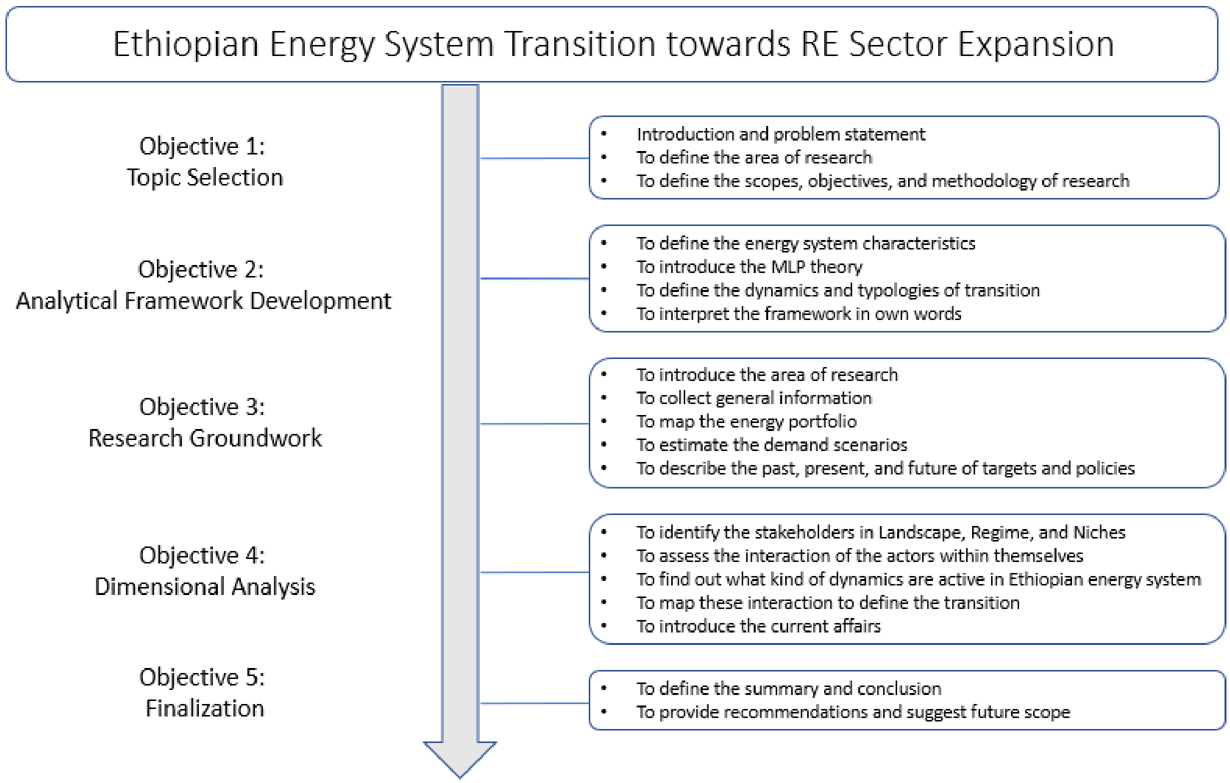

Figure 2: Objectives of the research, Source: Own illustration

1.4. Scopes of this paper

At first, the characteristics of energy transition from a conventional energy system to new and renewable energy sector expansion is described. With the help of graphics from the renowned World Energy Forum, a stakeholder listing has been made and along with that, their interrelation with each other and equal accountability for the transition process on a broader picture is presented. The energy trilemma which also functions as the system imperatives defines the need for a careful approach towards energy security, reliability, and affordability in an energy transition process is considered.

Further, the Multi-Level Perspective also known as Niche-Regime Theory (NRT) is introduced and the conceptualization of the energy transition chapter has been formulated which essentially lays the foundation stone for this thesis work. The area of research revolves around a country with great potential; Ethiopia.

Followed by that, the idea of how energy transition could be looked at through the lenses of socio-technical transformation is presented to understand the analytical framework in a more detailed way and this again is bolstered by understanding the dynamics and typologies of transition. Finally, with the analytical framework devised in chapter 1, the author had conferred his views on how the energy turnaround is being taken place in Ethiopia.

The scope of the analytical framework encompasses the work of Prof. Frank W. Geels on his theory of Multilevel Perspective. Along with that, the critics and discussions by other scientists were also kept in mind during this thesis work. A proper introduction of the research area which in this case is Ethiopia. The 'rich in resources' country which is still moving on its way towards development with very ambitious national plans and policies to become a Climate Resilient Green Economy by the year 2025. The country profile is expressed in form of various graphics and data.

The author then stepped on to the country's energy portfolio which comprises of subchapters like types of energy resources in the country, energy demand scenarios, energy mix, and energy policies. Typically, the energy demand scenarios have been put forward with respect to the results from Long-range Energy Alternatives Planning System (LEAP) analysis (a research work of Mr. Md Alam Mondal and group) to provide a general overview on Ethiopia's current energy demand and forecasts of sector-wise energy demand out to 2030 by providing two different scenarios. One being the 'Reference' scenario which will follow the current trend of development and project the results out to 2030 under business-as-usual conditions. Whereas, the other 'Alternative' scenario will point out three different cases scenarios namely universal electrification scenario, efficient lighting scenario, and improved cookstoves scenario respectively.

The final chapter of this thesis is about the dimensional analysis of Ethiopia's energy transition with respect to the analytical framework defined in chapter 2. The author mainly focused on the energy sector as a whole narrowing down electricity sector for the specific analysis because electricity is one important sector on which all other sectors are dependent. Along with that, other sectors like cooking, energy efficiency and security, and other sectors are included, but not very broadly in the analysis section. The interactions between the three different levels of socio-technical theory will be interpreted based on the findings from chapter 3. Followed by that, the author will present his own point of view about the whole analysis and some recommendations with concluding remarks. All the content taken into consideration for this paper lies in the time range of 1950 – 2018. A brief introduction to current affairs in the country is presented at the end of chapter 4 which will be important in the country's further development.

1.5. Methodology

The topic has been chosen after a thorough consultation with the thesis supervisor and some prominent people from the industry during the author's visit to Ethiopia in 2017. The motivation was to undertake a socio-technical analysis of the energy system transition towards renewable energies in a developing country. Various peer-reviewed journals, lectures and inputs from the author's supervisors, scientific articles, and online videos helped set up the foundation and eventually interpretation of the socio-technical analysis. By means of thorough literature review, an analytical framework namely Multilevel Perspective (MLP) theory has been chosen to understand the socio-technical energy transition of Ethiopia.

Different online websites, national and international reports produced by credible organizations, news articles, Ethiopia's government portals, INDC report, international and national policy databases have enabled the author to accumulate all the data necessary to formulate the country profile, energy mix, policies, past achievements, and future goals. Regarding the energy demand scenario, the LEAP analysis done by Mr. Md Alam Mondal and group (Mondal et al. 2018) has been summarized in order to project different future scenarios of the Ethiopian energy system.

The data used were compiled from different aforementioned sources. Lack of systematic practice to collect energy data in Ethiopia made it difficult to collect some important information and often had to depend on assumptions and extrapolation techniques. The final interpretation of Ethiopian energy system transition through the socio-technical analysis was done by the author based on his own understanding of the analytical framework and the supporting assimilated data collected throughout the formulation of this dissertation. Consequently, different conclusions and recommendations are drawn for this transition through socio-technical assessment followed by some pointers for further research ideas.

Chapter 2: Analytical Framework (Conceptualising Energy Transition)

2.1. Energy transition characteristics

Theoretically ‘Transition’ is a process or a period of changing from one state or condition to another. This dissertation deals with the transition of Conventional Energy System to Renewable Energy System. Now the question arises, what kind of ‘Transition’ will that be?

The process by which the energy systems which are driven by conventional sources of energies start integrating clean or renewable sources of energies in the mix and eventually increase the RE share in the system is called as ‘Transition towards Renewables’ both on a scale of Production and Consumption.

The whole development scale of energy demand in the beginning till 18th century was accountable to site-specific resources which were majorly dependent on biomass. Historically, it is evident that the energy demands grow with the development of the economies, be it of a small area, a region, a country and more. When the site-specific biomass resources proved to be inadequate due to the rise of economic activities by the advent of industrialization, coal was found, introduced and it quickly became a key source of energy which drove the era of industrialization. As the steepness of the learning curve increased with more advancement of machinery and mobility, oil came into the picture in the 20th century. However, hydro-based resources were also playing key roles in sufficing the energy demands. (Carnegie Mellon University 2003)

Energy has always been a key element in human lives. It is the driver of a country’s economy and its secure availability ensures industrial processes and domestic services including lighting, heating and cooling, cooking, transport, and communications. Almost all the countries in the world, in one way or the other, are confronted with global problems like economic and social development, poverty eradication, adequate food production, health and well-being, ecosystem conservation, peace, and security. All these problems have a common link connecting them and that is the energy sector and its role in addressing them. The energy systems across the world are going through a rapid change driven by forces like consumption and supply patterns, technological advancement, and policy amendments. Not to forget the fact that with time, the energy systems will have to provide for more people as the global population increases and the target of ‘access to clean and affordable energy to all’ as a sustainable development goal will probably have been achieved. (World Economic Forum 2018)

As pointed out International Energy Agency (IEA), “Energy is very important in driving the other sectors such as food, water, shelter, mobility, and communications and this shows how big a role the energy system plays to lead the transition in an economy”. Energy transition is a long-term process and along this process, all the stakeholders of the system together make the ‘energy triangle’ (see fig. 3). Now the question is how does an ‘effective energy transition’ look like?

According to the World Economic Forum (WEF), *Effective energy transition is a timely transition towards a more inclusive, sustainable, affordable and secure global energy system that provides solutions to global energy-related challenges, while creating value for business and society, without compromising the balance of the energy triangle*. (World Economic Forum 2018) Basically, the energy triangle constitutes 3 main points:

- Environmental sustainability
- Security and access
- Inclusive economic development and growth

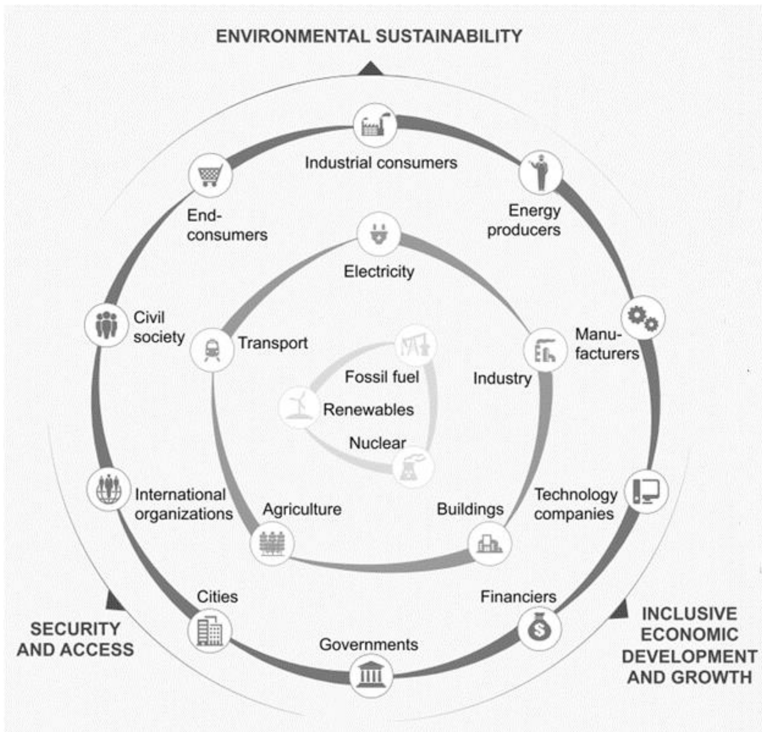

Figure 3: The Energy Triangle, Source: (World Economic Forum 2018)

Achieving simultaneous development in all three sectors is quite difficult because of various circumstances and priorities. On the other hand, different countries have different starting points for the transition, so the outcomes of specific actions will hardly result in a similar way for two different nations especially when the successful policies from developed countries being tried to be implemented in developing countries. Reasons are not homogenous, factors like the market, prices, labour force, energy mix, infrastructure, existing policies, governments, consumers, etc. are responsible to drive the change. Undoubtedly, the energy transition potentially provides new opportunities, technologies, employment and facilitates a clean and green economy, but it also has unpredicted socio-economic shocks due to the complex process of multi-stakeholder interaction and collaboration. Therefore, at a country level, the very core strength of an energy system will depend on its performance imperatives (see fig. 4).

According to WEF, "*Given that energy is still coupled to economic development and growth, countries will need to carefully approach security and reliability while maintaining affordability to ensure that their citizens can access public services and industries can remain competitive*". (World Economic Forum 2018)

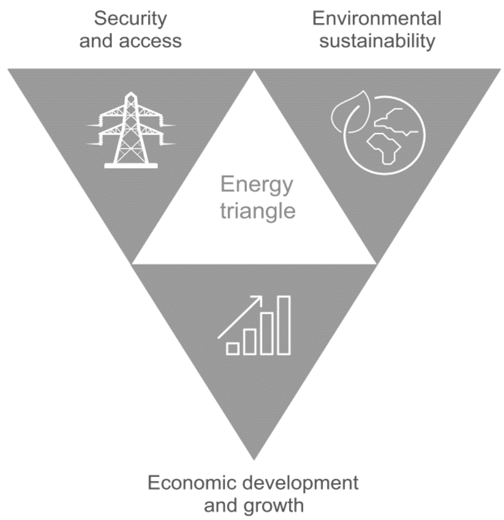

Figure 4: System Performance Imperatives, Source: (World Economic Forum 2018)

New technological innovations in energy technology in the field of production, consumption, storage, and transformation have managed to reduce costs, created employment, and fostered the carbon reduction from the energy sector. New technological advancements like digitalization in the energy systems allowed real-time automated tracking which provides an added advantage of monitoring the energy use and thereby making the 'efficient use of energy' easier and more achievable. The decreasing cost of renewable energy technologies has resulted in the creation of new jobs. As per a latest report by the International Renewable Energy Agency (IRENA), 9.8 million people around the world in 2016 were employed in the renewable energy sector which is a 1.1% increase over 2015. (IRENA 2017) Nevertheless, this positive trend is a good indication towards unlocking the energy trilemma, but more efforts are the need of the hour.

The enabling factors of the energy transition process control the aforementioned 'system imperatives'. They ensure the stability of social, political, and economic structures of a country to facilitate the transition to be reliable and inclusive which brings secure economic development. WEF identifies six dimensions of enabling factors (see fig. 5). Energy system structure defines the readiness of the country for its transition. The accountability of political commitments and funds to support and finance the policies. Regulatory frameworks and the ease of doing business are also decisive enabling actors as they provide flexibility and open new ways for the economy by incorporating latest market designs, multilateral partnerships, and new innovations. Likewise, human capital, infrastructure, and institutions are also the distinguished dimensions which also acts as the enabling actors. Finally, since energy transition will vastly depend on social acceptance, therefore, consumer behaviour will play a pivotal role in the future of a country's energy turnaround. (World Economic Forum 2018)

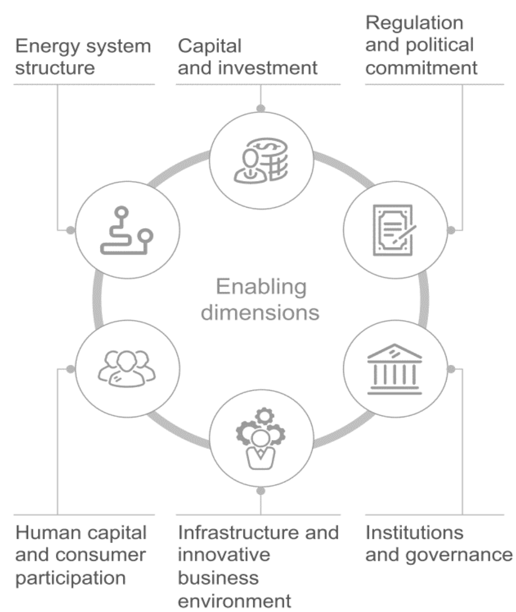

Figure 5: Energy transition enabling factors, Source: (World Economic Forum 2018)

The electricity system is contributing a lot to the transition. At the moment, the electricity system, as mentioned in the beginning is driven by digitalization, decentralization, and electrification. (World Economic Forum 2017) The accelerating decentralization is boosting up the electrification drive and hence increasing the energy access in remote locations where the grid connections are absent. Electrification through renewable resources undoubtedly is a long-term measure of carbon reduction and with its penetration in new sectors like transport will surely have a positive impact in the future. Hence the convergence of these trends reinforces and amplifies their individual contributions. Although the gap between demand and supply patterns shouldn't be very wide, with correct decision measures, political goodwill and supporting policies, this mismatch can be addressed. According to IEA, "*the energy per capita has peaked in most mature economies, on a global level, economic growth, and energy consumption are also being decoupled at least in developed nations. For example, in 2016, global energy demand grew by 1.1%, while GDP grew 3% in the same period*". On top of that, countries today are emphasizing on policies to channel the consumer behaviour towards energy-efficient substitutes or options. (IEA 2017)

2.2. Niche-regime theory as the analytical framework

When it comes to transition, there has been a lot written and analyzed and then written again with updates, critics, and further discussion. Recent transition studies point out that transitions will not merely be some technological fixes but an umbrella under which the economic, political, institutional and socio-cultural changes resides. (Berkhout et al. 2012) To understand this kind of changes for a better sustainable future, multi-level perspective (MLP) theory for sociological transformations is a relevant structure. MLP is a means for explaining how technological transitions take place. It provides insights on how technologies hit transition and evolve to fulfill the social needs. It explains the interaction of various entities of transition such as actors, environments, innovations, and others. The MLP emphasizes how the alignment of trajectories within levels, as well as between levels, will produce transitions. The whole idea is based on a different hierarchical level as a nested structure meaning that regimes are embedded within landscapes and niches within regimes (See fig. 6). (Geels and Schot 2007)

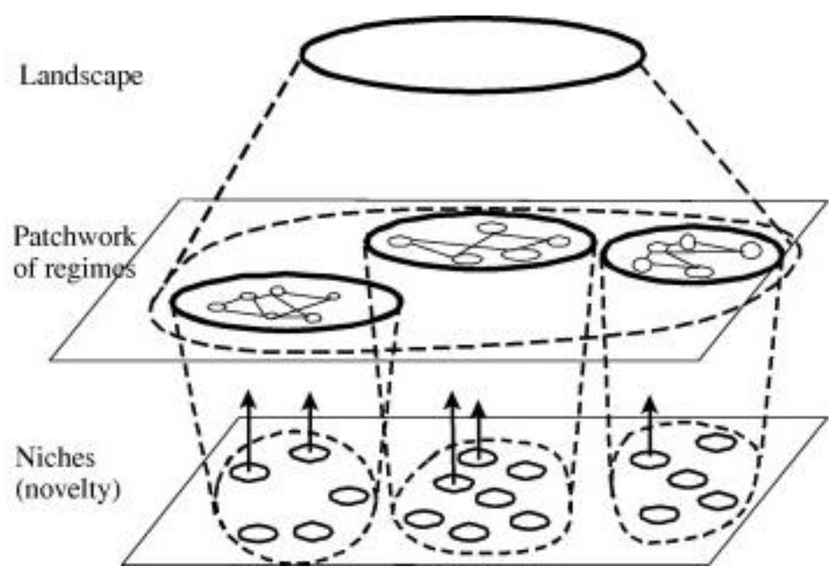

Figure 6: Levels in multi-level perspective, Source: (Geels 2004)

These three levels are micro level niches, meso level regimes, and macro level landscape in stratified order. These three levels work under a framework of socio-technical systems.

Technological Niches: It is the level at which space is provided for radical innovation and experimentation. This level seldom comes under market and regulation influences and act as the most driving force to implement interactions between actors that support product innovation. There are opportunities for most fundamental innovation at this level because of the scope of novelty (new invention), security from the selection process (which comes at regime level) and safe environment for new experimentation and idea refinement which may or may not lead to ground-breaking innovation in future. Primarily, a niche develops at the lowest level (micro level), which independent from the rules of the regime, for example, by government subsidies or regulatory exemptions.

As niches act as incubation rooms facilitating the opportunities for 'learning by doing' to increase the scope for research and learning experiences. They provide time and platform for new ideas to generate, test, and prove. In due time, it creates an establishment of supporting networks, for example, supply chain and industry contacts which support the niches with its initial development. During this period, in order to break through the regime level, emerging technology has to prove its potential over the existing technologies which are technologically and economically superior to it. (Davidson et al. 2018)

Socio-technical Regime: It is referred to as the middle layer of the MLP theory where all the games are played such as dominant practices, rules, and technologies that provide stability and reinforcement to the prevailing socio-technical systems. According to Nelson et Al., in former days, the technological regime constituted cognitive routines or preset rules being followed by the engineering community and bring about the technological innovations. (Nelson and Winter 1982) The socio-technical regime on the other hand, went a step further by including an expanded range of social groups, for example, scientists, policy makers, users, and special interest groups (external contributors to technological development) as well along with engineers. This whole scale of patterned development was traced along the 'technological trajectories'. (Geels and Schot 2007)

Pertaining to the evolutionary economics, the selection process and retention function which is absent at the niche level are introduced here. This mechanism strains out the inefficient and unsuccessful innovations to provide convenient platforms for the successful innovations to thrive. Due to the presence of the regime level in the middle, sandwiched between the niche and landscape, most of the radical changes enter here and gradually struggle for expansion to achieve optimization. These fundamental changes may or may not threaten the vested interests associated with the already established regime actors. In simple words, 'resistant to change' or the 'momentum of key industries', for example, current big names in the oil and gas industries showing interests towards green energy solutions.

Socio-technical Landscape: It is the whole external environment which is beyond the direct influence of both niche and regime actors. The dynamics at this level witness very slow movements but these changes have the potential to have certain impacts on the regime by putting external pressure on it and enabling intra- and inter-level interactions among the actors. On a bigger picture, socio-technical landscape mostly includes the various materialistic aspects of the society and offers various prospects for action in order to enable transition, for example, material and spatial arrangements of cities, factories and electricity infrastructures.

The MLP theory over the years has gained recognition in transition studies as it accommodates both the ideas and notions from science and technology studies, evolutionary economics, and sociology. Each level is conceptualized as a heterogeneous socio-technical configuration having each level differing from the other in terms of stability and scale. Nevertheless, the network of actors at the niche level are small, new, and unstable. Generally, risk-takers like entrepreneurs and innovators are the major contenders in this group. A great deal of effort is necessary for these actors to uphold the niches because of the high risk of uncertainty at this level. However, the socio-technical regime is more stable in this regard and the networks are larger in terms of both configuration and structure at this level. The MLP states that transitions come about through the interactions between the processes at different levels. (Geels and Schot 2010) The following figure demonstrates a schematic representation of these transition dynamics (see fig. 7).

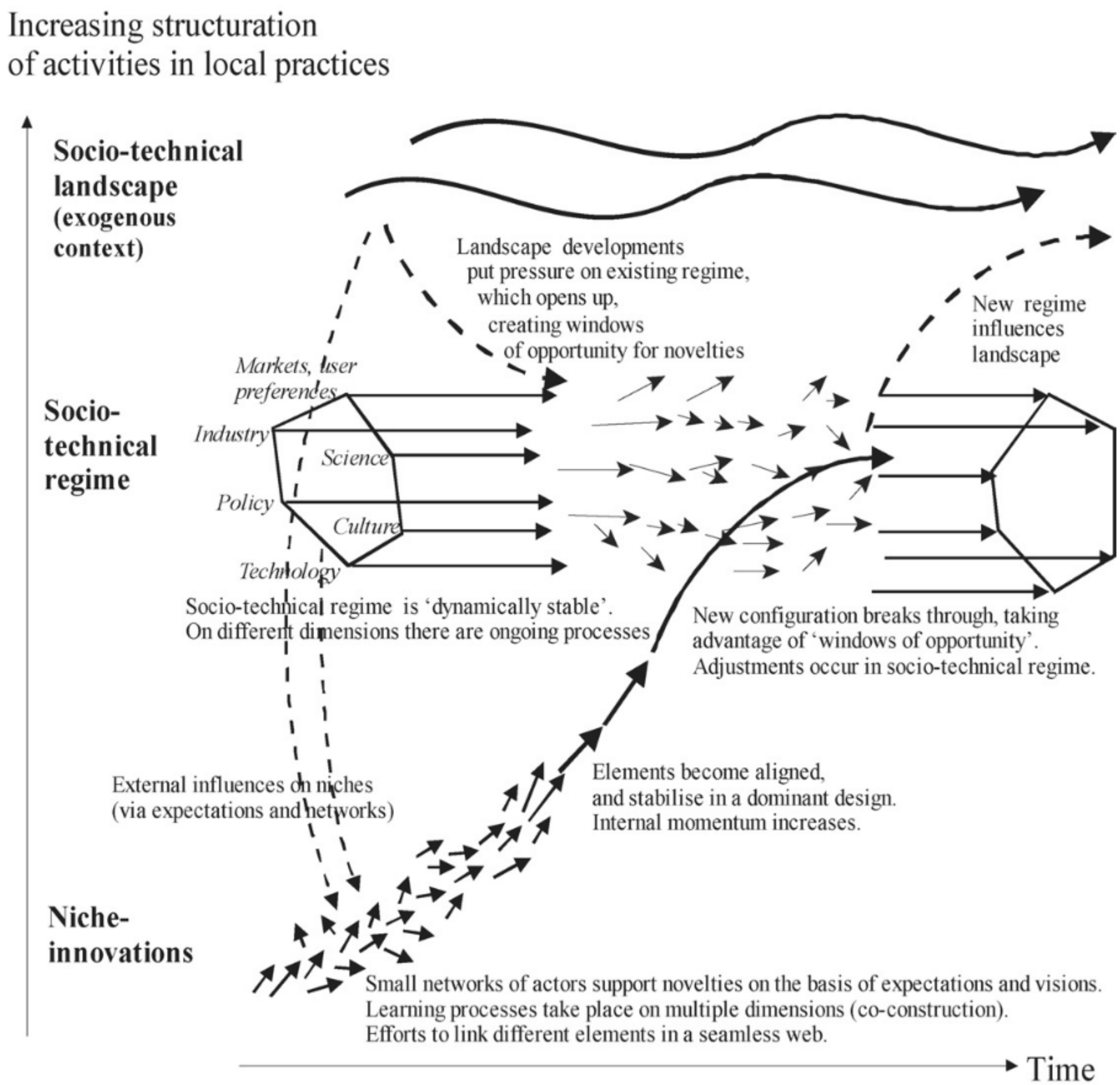

Figure 7: Multi-level perspective on transitions, Source: (Geels and Kemp 2007)

As Mokyr in 1990 said that "*the environment into which these seeds are sown is, of course, the main determinant of whether they will sprout*", the indication was towards the niche innovations which are vital seeds of transition, but they don't follow a straight-forward path towards being successful. The multi-level interaction as shown in the figure above plays the key role. Social networks in the niches are influenced by strong ongoing dynamics at regime and landscape levels.

Now in simple words 'What blocks transition?'. To understand this, one needs to understand that new ideas are the seeds of change and the hindrances to their growth include their own incompetence in terms of novelty and the 'resistant to change' nature of the established system. For example, novelty issues like the intermittency of new renewable technologies is a drawback and couldn't fully replace the conventional power systems and regime resistance issues like infrastructure requirements, user practices or policies etc.

Another possible reason would be the conflict of interest between established vested interest groups at regime level opposing new niche-innovations. Take conventional energy sources market opposing the clean renewables for instance. As long as existing regimes are stable, novelties have little chance to break through however, it is not always the case. The external landscape changes pressurize the existing regimes to make way for novel technological innovations as niches. For example, climate change factor and relative oil prices have opened up windows of opportunities for new and renewable sources of energy. These interactions between the levels cater to the realignment at regime level and change the way it looks over the time. (Geels 2010)

2.3. Energy transition as a socio-technical transformation

Along with the energy transition and its long-term nature, the other but most important thing to be mentioned is the societal factors in transition pathways. In section 2.2 above, the theory of MLP is presented. With many years prominence in the transition studies, MLP theory helps assess a successful socio-technical transformation in any specific field coupled with new and innovative ideas with massive potential at niche level entering the regime under the external pressure from the landscape. According to Geels and Schot, "*There is no simple cause or driver in transitions. Instead, there is co-evolution within and between levels, i.e., processes at multiple dimensions and levels simultaneously. Transitions come about when these processes link up and reinforce each other*." (Geels and Schot 2010)

Section 2.1 highlighted on how important a role the energy sector plays in a country's economy and therefore, it is potentially at top priority to be the driver of transformation because of the interdependence of other sectors on energy. The previous chapter also listed out the enabling actors responsible for giving structure and to facilitate the transition process. This section sheds light upon how energy transition could be scaled with a socio-technical approach. Different approaches that hover around innovation and technologies with sociocultural, political, and economic elements also frame the problem statements of energy transition as a socio-technical challenge. Davidson et Al. pronounce that, *"at the core of transition studies, there is the ambition of a goal-oriented, transformative change*". Contributing to such a goal requires a sound understanding of not only the socio-technical relations that create the stable structures characteristic of the energy system but also the dynamics of systemic change and of governance strategies collectively aiming for a more sustainable energy system". (Davidson et al. 2018)

The multilevel perspective of socio-technical transitions comprised of such research, which defines the structuration of the three distinguished levels. Firstly, a socio-technical landscape which are profoundly rooted societal and cultural norms and/or values where the dynamics changes as slow as the levels of society. Secondly, a socio-technical regime which is considered as the engine of change because of its stable structure and it offers the selection environment for new technologies. The last one being the technological niches which are the new and emerging technologies looking for their turn to a breakthrough in the regime. (Rip et al. 1998) Thus the MLP discusses the integration and interaction of the actors involved in multisectoral processes of transition to define how energy-society relations can be seen through the socio-technical lens.

The evolution of energy dates back to the early civilizations of human beings where muscles (both humans and animals) used to be the source of energy to do work and food was the fuel. With the invention of fire and the wheel which are considered as the important inventions of mankind, things started getting easier and energy usage for different activities like cooking and heating began eventually. With the domestication of plants and animals leading to agricultural advancements post the hunting and gathering era, small village establishments began to take place eventually forming towns and cities. Use of hydropower and then the discovery of oil drove the economies (metal works, electricity, and steam-powered transport) and introduced the industrialization to the world. Similarly, with the discovery of oil and the invention of automobiles, the global energy use took a great acceleration.

Nuclear energy is promising in terms of electricity production, however the threat it poses with radiation, nuclear meltdown, and radioactive waste is intimidating. (Greenpeace 2018) Overall, these anthropogenic advancements are in one way or the other contributing to 'climate change'. (Rahmstorf 2008) In the figure below (see fig. 8), an alarming rate of increase in carbon dioxide levels over past centuries are displayed. Therefore, an inclusive socio-technical transition will ensure a momentum towards the 'Paris Climate Summit' goals. Over the past few decades, there has been decent growth in the share of renewables in the world energy mix which is a good sign in leading the transition, however, more efforts should get prioritized now. So, the socio-technical setting in the energy sector is the adoption of not only the energy resources or infrastructure but also the societal behaviour and institutional elements, for example, the individuals and the organizations. (Foxon 2010; Geels and Schot 2010)

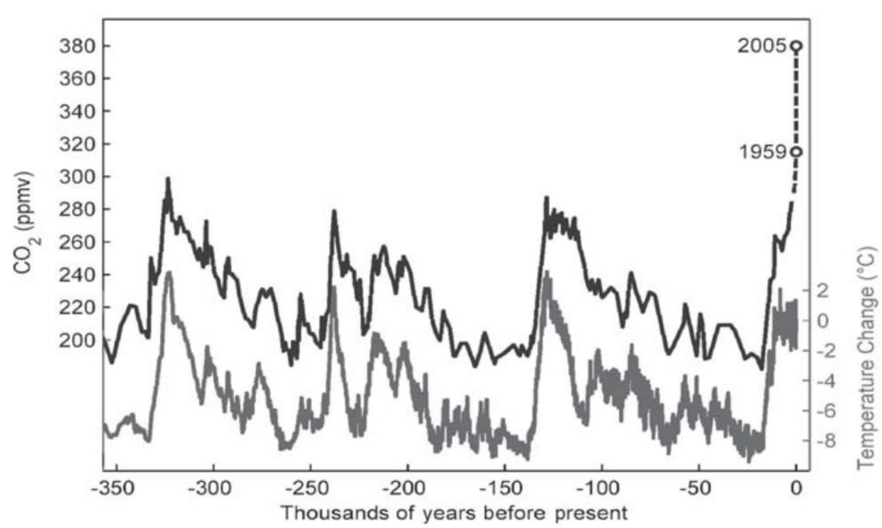

Figure 8: Climate History of the Past 350,000 Years, Source: (Rahmstorf 2008)

To capture the key characteristics of socio-technical transition of energy systems, it is very significant to first try and understand the previous development trajectory of development from the beginning. The paragraph above explains the evolution of energy and its development over the timeline of human history. This will help understanding or interpretation of future transition strategies. Following up from the previous section 2.2 along with the evolution of energy systems, one can trace a fact that each time there was a radical innovation post the discovery of energy source, for example, invention of stoves for cooking,

steam engine for electricity, transport and other motion-related work, etc. and these innovations as niches, after competing with their counterparts (other innovations during those times) made their way to the regime.

At the regime level, after going through lots of evaluation and the pressure of selection, they established themselves as an incumbent part of the energy system mix over the time. A layering of new technologies over old: coal, then hydro, then coal again, then nuclear, gas, new renewables, and so on. Rosenbloom and Meadowcroft stated that "*we need to put our focus on the shifting societal comprehension of the relationship between electricity supply* (considering the broad energy system for this thesis) *and the economic development, ownership structures, stakeholder interaction, and regulatory frameworks*". (Rosenbloom and Meadowcroft 2014)

Socio-technical landscape in this whole evolution of energy system throughout the time has been the most important factor. As it is largely defined by the changes and modifications in the overall behaviour according to the social needs during a particular time and area, it is fairly impossible to draw out concrete examples of concrete landscape unless when it is sector-specific. In this complicated case like energy system, apart from social factors, natural and anthropogenic events and elements also define the landscape, for example, climate change and natural disasters are nature induced, whereas, political system, war, terrorism, etc. are the examples of human-initiated activities. The relevance of these factors can be assumed by the impact they can potentially cause to a country's energy system. The next section is going to define how the shifts in the dynamics of these transitions occur with respect to the different mechanisms of a regime shift.

2.4. Dynamics and typology of transition

The essence of transition always speaks about the multisectoral shifts, their emergence and their correlation between former shifts across the trajectories of different levels (socio-technical in this case). Over a period of time, these movements collectively witness the transition in a given geographical area. The systems at the multi-sectoral levels are the socio-technical systems constituting elements or entities like science and technology, markets, cultural meaning, regulations, production and supply mechanisms and associated actors, and infrastructure. (Geels 2004) This cluster of elements together creates a socio-technical system. A detailed table of all the following transition dynamics types is elaborated (see table 1) below. The elements of socio-technical systems are created and maintained by actors such as firms, research institutes, universities, and policymakers who are considered as supply-side actors. Whereas the demand-side actors usually constitute users, media, and vested-interest groups. (Geels and Kemp 2007).

There are mainly three different ways of interactions between all three levels in a socio-technical setting.

- Reproduction and Reconfiguration: Intra-level
- Transformation (Moderate and Avalanche): Top-down
- Transition: Bottom-up

Table 1: Different mechanisms in change processes, Source: (Geels and Kemp 2007)

	Reproduction	Transformation	Transition
Levels Involved	Regime dynamics	• Pressure from landscape • Adaptation and reorientation in the regime	• Pressure from landscape • Increasing problems in the regime, and attempts at reorientation • A new innovation in niches that eventually breakthrough
Role of Actors	Incumbent regime actors	• Pressure from outsiders • Incumbent regime actors respond through reorienting innovative trajectories	• Pressure from landscape • Incumbent actors fail to solve regime problems • Outsiders develop new innovations

2.4.1. Reproduction and Reconfiguration:

It is more of an intra-regime change process irrespective of any influence from or interaction with the socio-technical landscape and novel niches. In absence of any external pressure from the socio-technical landscape, the recreation (often upgradation) of existing rules and directions by the incumbent actors take place. A firm settlement is created for the social groups (associated with the regime) to interact with each other. There is no radical change taking place in the orientation of the dominant actors, knowledge pool, and established technologies in place. This setting gives the platform for incremental and cumulative change along trajectories (see fig. 9). This stable state is quite regular and dynamic at regime level because many factors can still bring different levels of entropy to this stable state, for example, sunk investments, role expectations in networks, standards, contracts, cognitive routines. (Geels and Kemp 2007) In other words, this is just the law of nature and the incremental innovations are inevitable to occur to avoid stagnation and being outdated.

Although the presence of few radical innovations may won't affect much in this process since they have hardly the potential to breakthrough as long as the regime stays dynamically stable, it will reorient itself accommodating the changes. Reinforcing landscape developments helps in the stabilization of the regime level and the internal issues are being dealt with locally as well. (Geels and Schot 2007)

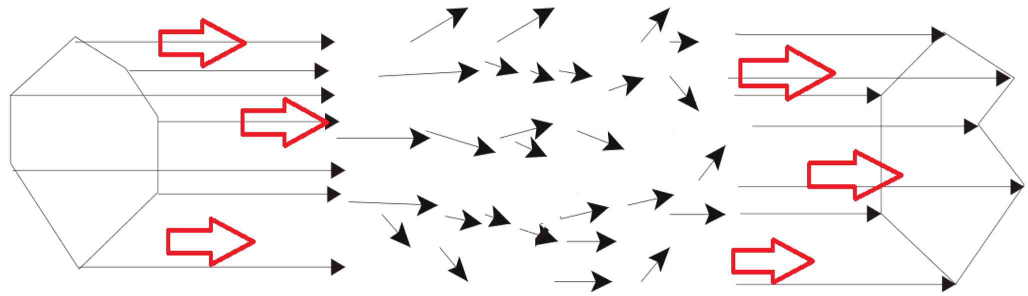

Figure 9: Intra-level interactions in the socio-technical regime, Source: (Geels and Kemp 2007)

2.4.2. Transformation Path (Top-Down Approach):

This change process comprises of inter-level interactions. The synergy here is between the socio-technical regime and socio-technical landscape. Very seldom, niches come into play and influence this interaction, however, the scale of interference is quite negligible in this change process. The idea behind this change stands on the mechanism of socio-technical landscape putting moderate pressure on the regime and leading to many changes and orientation shifts at the regime level to translate the direction of innovation. The process is otherwise known as ‘disruptive change’ which includes reformulation of guiding principles, visions, goals, relative costs, and incentive structures must also be revisited and along with that, the problem agendas are to be structured again together with regulations and perceptions of opportunities.

The adjustment and re-orientation to external landscape pressure do not happen in a mechanical fashion, but through negotiations, power struggles and shifting coalitions of actors. (Geels and Kemp 2007) This moderate external influence comes from the landscape at a time when niche-innovations are not adequately developed to challenge the existing regime actors, and, in this case, the socio-technical regime follows a path of ‘modification of direction’ or ‘reorientation’. The pressure from the landscape manages to create successful changes only when they are well received and acted upon at the regime level. Sometimes the outsiders (actors outside the socio-technical setting) draw the attention towards the negative externalities by translating the landscape pressures which often gets neglected by the dominant regime. (van de Poel 2000, 2002)

This top-down approach is often necessary as the incumbent regime entities show resistance to change and therefore the transformation in the social networks defines the first step of a transition in large scale. The previously considered assumptions and the cliched solutions around them are challenged by the new social network under the pressure of outsiders, the general public and regulatory bodies which potentially include new issues on the problem agenda to address. Such outsiders may demand responses from the dominant regime actors by expressing concerns over negative externalities of the existing system. But, in the transformation process, these outsiders hardly have the capacity to replace the existing system by developing new technologies. (van de Poel 2002).

Therefore, the existing socio-technical regime actors have always a chance to reach up to these changes and mold themselves accordingly in order to follow the redirection of the development trajectories in the same existing system. On the other hand, there might be always a chance of creation of a totally new system change out of the old ones (see fig. 10).

Landscape pressure unless it is under the criticism of outsiders won't impose the changes at the regime level. It generally includes conflicts, contestations, power struggles or dedicated translations. Socio-institutional dynamics are vital along the whole process, with social groups acting to change regime rules directly. In response, strong regulations, public opinion, and societal protest acting as the selection environment are being used in the reorientation according to their adaptive capacity. New regimes are being born out of the old ones through aggregate adjustments (see fig. 11) and these changes mark the evolutionary dynamics at the socio-technical regime level.

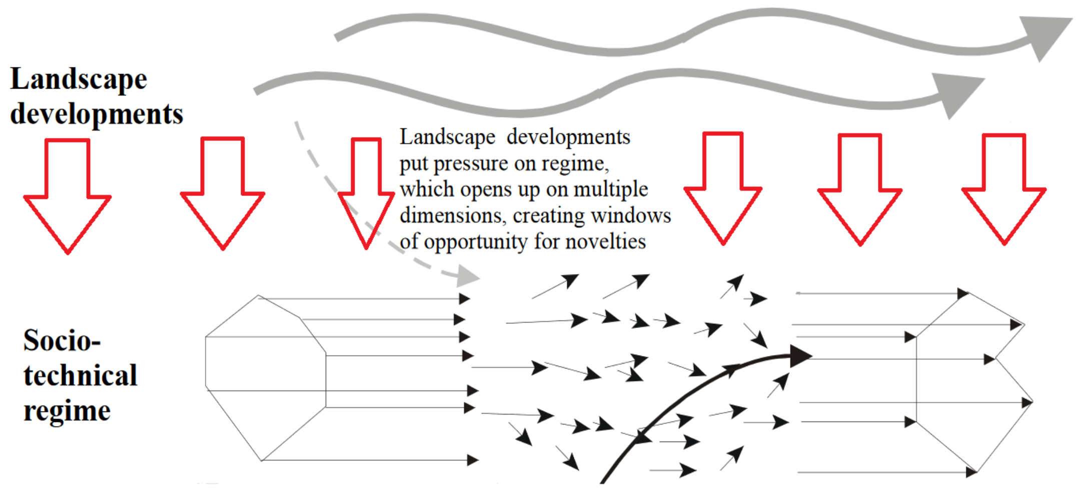

Figure 10: Top-Down socio-technical regime shift scenario, Source: (Geels and Kemp 2007)

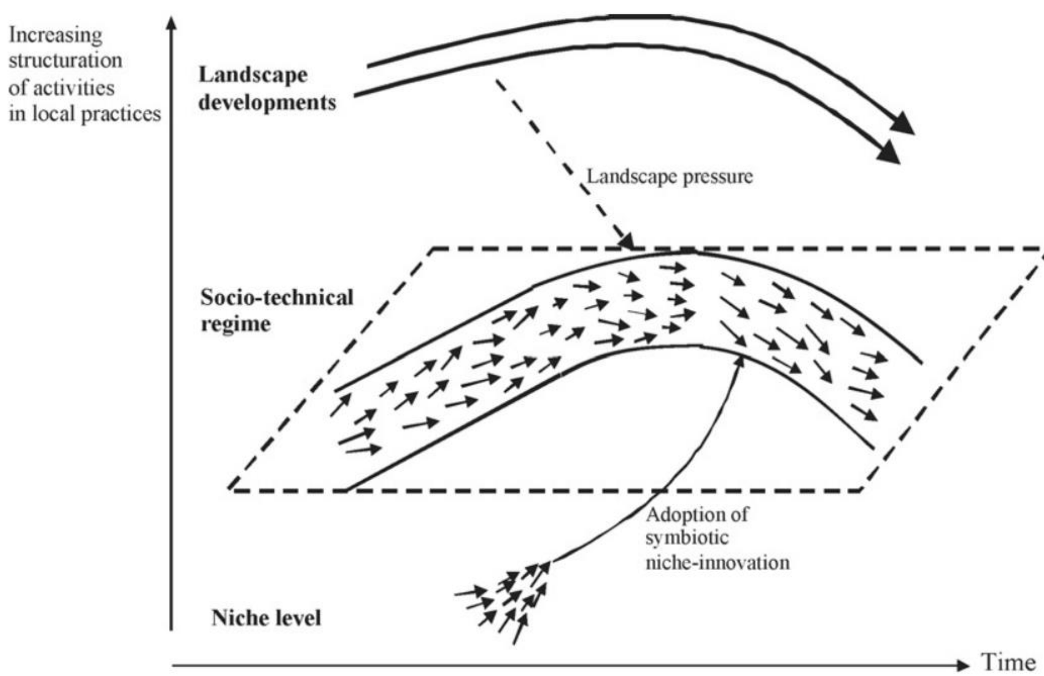

Figure 11: Transformation process pathway, Source: (Geels and Schot 2007)

2.4.3. De-alignment and Re-alignment path (Top-Down Approach)

In this case, when socio-technical landscape goes through sudden, divergent change on a big scale which can also be called as avalanche change, then that pressure which is created on the regime can cause its entities to lose faith and it leads to the de-alignment or erosion of the regime. In times of the unavailability of potentially developed new niche technologies to enter, perform, and replace the regime entities, then gives birth to suitable opportunities for multiple developing niche innovations to provide alternatives by simultaneous entry to enter, co-exist and compete for attention and resources. Consequently, one niche-innovation outruns the other to become dominant and hence form the core for re-alignment of a new regime. (Geels and Schot 2007)

This kind of transformation pathway is much rapid than its predecessor since the landscape exerts immense pressure on the regime which increases the internal regime issues to an extent that it may also often rip it apart. That is the reason why this avalanche change leads to collapse or de-alignment of the incumbent regime actors. This destabilization at socio-technical regime level create surplus uncertainties regarding the reorientation process internally and it is due to the loss of faith on its own potential to revive things (guiding principles, user preferences, selection criteria, regulations, etc.) and keep up the development process without any external influences. The lack of stable rules results in more investigation or exploration in more than one direction along the socio-technical levels. There is a prolonged period of co-existence, uncertainty, experimentation, and competition for attention and resources. Eventually, one niche-innovation gains momentum and becomes dominant, followed by re-alignment and re-institutionalization in a new sociotechnical regime (see fig. 12). (Geels and Schot 2007)

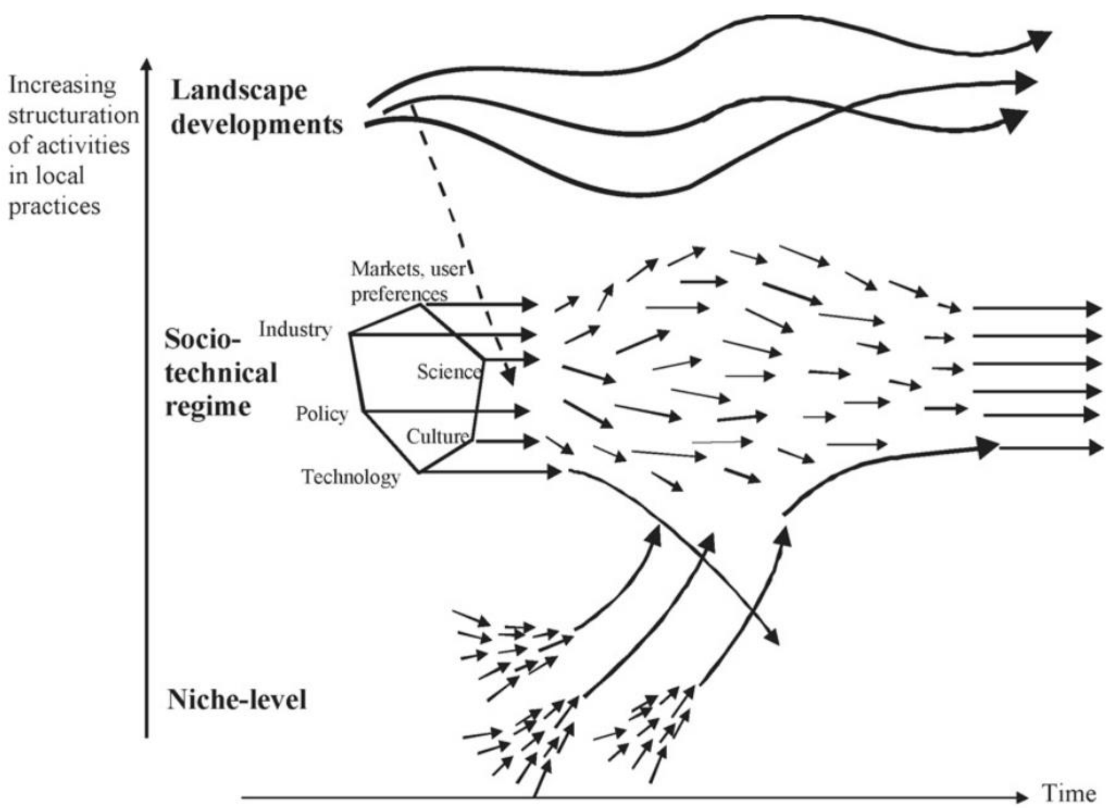

Figure 12: De-alignment and re-alignment transformation pathway, Source: (Geels and Schot 2007)

2.4.4. Transition (Bottom-Up Approach):

The transition can be defined as a turn-around at a major scale where the interacting actors hail from all the three levels (macro level socio-technical landscape, meso-level socio-technical regime, and micro-level novel niches). It deals with whole inter-level shifts to new different trajectories on the basis of interactions. This transition involved changes in the socio-technical system (e.g. technologies, knowledge base, infrastructure, regulations, user practices, cultural preferences), social groups and regime rules. The interaction, as explained in above chapters, starts when there is discomfort at the landscape level and it exerts pressure on its subordinate level to facilitate reorientation at socio-technical regime level. In cases of failure of such interactions, it creates opportunities for new and novel technologies in the form of niches to come into play and assess their potential for becoming the part of the transition. These niches are carried by a new network of social groups from outside and often have the possibilities of challenging the existing way of regime either to bring about adjustment at the meso level or penetrate themselves in form of changes. This breaking through processes, at times, phases out the current ongoing technologies at work in the socio-technical regime with emergent niches taking over and becoming the new regime. (Geels and Schot 2010)

However, this phasing out process can otherwise be called as 'creative destruction'. With the collapse of some incumbent technologies, the actors associated with them are also vulnerable to phase out, unless they reform themselves and inculcate the new technologies and create room for hybridization. According to Van de Poel, rules comprising an existing technological regime exert an influence on its future development. (van de Poel 2002) This autonomy gives the socio-technical regime an option to still be on the picture and play with the current inter-level interactions. That is the biggest reason why the process of 'socio-technical transition' is not very fast and it needs its time. However, once the change has brought about or the transition has taken place, a new period of dynamic stability and reproduction begins.

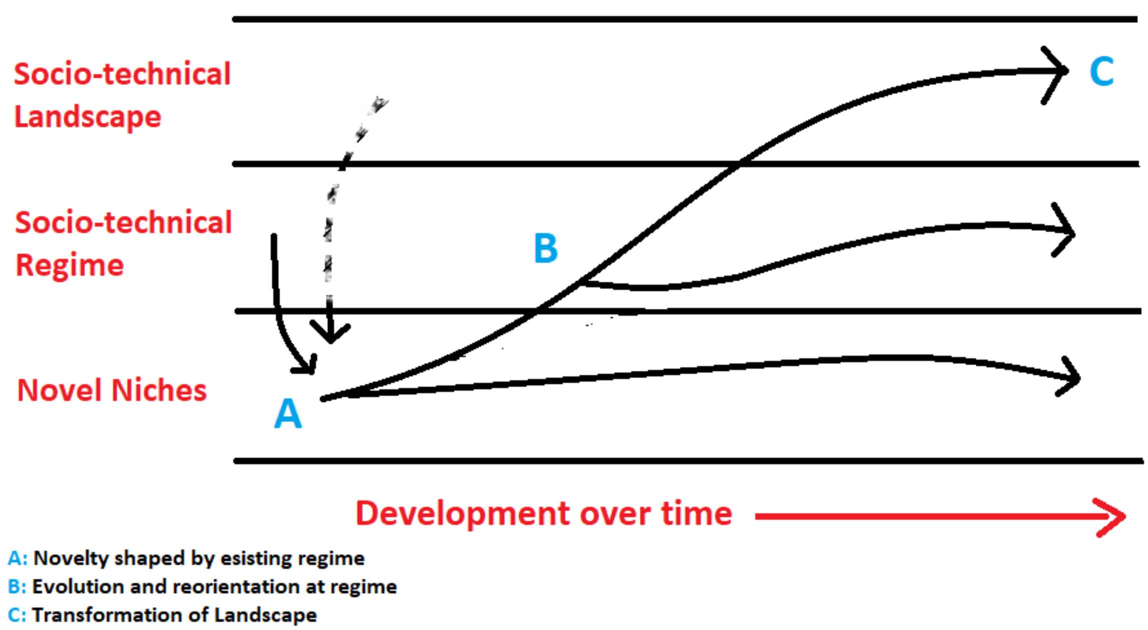

Figure 13: Bottom-Up socio-technical regime shift scenario, Source: (van de Poel 2002), Own illustration

2.5. Author’s own interpretation of Socio-technical energy transition and introduction to Ethiopian context

Thousands of reasons can be drawn on the plate why different interest groups have asked for and brought about the changes. Over time, various transition categories appeared, for example, social equity, gender equality, reduced unemployment, as well as nuclear disarmament. (Frans Berkhout, Adrian Smith, Andy Stirling 2003) However, the current trend indicates a deliberate effort towards bringing a change in the field of environment. The concept of sustainable development first derived in the year 1980 and since then it has become instrumental to draw political attention towards environmental challenges and to act as an objective in the international, national, and regional policymaking. (Frans Berkhout, Adrian Smith, Andy Stirling 2003) Decades of research has already been undertaken by social scientists in this field. Transition management theorists have done a decent amount analysis of technologies both sociologically and historically. Therefore, technologies were shown or proven to be clustered within particular economic, social, cultural and institutional structures and systems of beliefs.

According to the author, it can also be seen from the opposite perspective where technological configurations can also impart changes or influence the structures around them, for example, the invention of wireless telephones increased its usability of telephone service as it became more convenient for the users to move and still be able to use the telephone services. The multi-level approach was only developed by the transition management theorists to induce the social factor to the work of innovators, engineers, and entrepreneurs who were generating new ideas and eventually converting them to technologies. This multi-level theory gave birth to the socio-technical landscape which lies at the macro or broader level encompassing everything that’s happening within itself. At an intermediate meso level stands the socio-technical regime which is the strongest and most important functional unit of the society. Micro-level niches are however the game-changers since it is because of them the regime runs and hence the landscape. Niches are those seeds of development which sprout and if handled carefully and nurtured well, have the potential even to challenge the regime entities either to co-exist or to drive them out to replace them.

This MLP theory with its three levels of socio-technical arrangement has great potential and it is very influential in many different ways. It illustrates how the seeds of ideas in fertile environments nurture the ideas to become a firm part of societies. The movements throughout its trajectories (from micro-level niches to macro-level landscapes) showcase ‘configurations that might work to configurations that actually work. Throughout this journey, the socio-technical configuration adapts well to its context to become more stable both technically and in terms of the social relationships and exhibits growing reluctance to rewind. Nevertheless, the MLP approach certainly creates an understanding of the nuances of socio-technical transformations. Therefore, it is be interesting to study the case of Ethiopia and conditions which facilitates its energy transition.

The presence of different starting points to comprehend the idea of transition, but all the conditions tend to enable the process of change as discussed in the previous sections. The so-called guiding visions at the regime level will always be the destination (the goal of the transition) which has to be reached by the actors on the path to transition through different trajectories on the basis of the interactions. Often it happens that these guiding visions could lack ambition and may result in failure, for example, successive innovations in a very specific field.

However, factors like social feasibility and desirability of the new change decide on the fate of its existence and ensure the transition. On top of that, the author agrees that the creation of a support mechanism and expectations for a vision can be a very important strategy to attract attention and resources and hence enable the development process of new niches.

As described in the introduction chapter, Ethiopia is an interesting country with its rapidly growing economy and with ambitious goals to become a middle-income country by 2025, which includes aggressive power generation and access targets. (USAID 2018b) The scale of this transition of Ethiopia would be fascinating to analyse with the help of multi-level perspective theory. The next chapter will be about the country itself and about its history, climate, geography, economy, energy portfolio, political status quo, and its future plans. Together with all this information, Ethiopia's energy system transition towards becoming a green economy prospect will be assessed.

With the help of the analytical framework developed in the previous chapters, the different dimensions of transition being taken place in the country will be assessed. Questions like what kind of trajectories are active in terms of the dynamics of Niche-Regime theory will be answered. The different stakeholders from different sectors which are directly and indirectly associated with the energy sector and hence accountable for this transition studies will be introduced in the next chapter. Next chapter is also going to describe the current status quo of the country pertaining to its energy sector. The position of the Government of Ethiopia (GoE) now and in future will be discussed with the help of various policies from the past and the new policies which are in force at the moment.

International, national, and regional regulations and organisations will also come into picture during the individual introduction of the energy resources contributing to the energy mix of the country. The role of the authorities responsible for policy making, technological deployment, and financial planning will also be discussed in the concerned subchapters with the support of facts and figures from different sources. Chapter 3.2.3: Energy Demand Scenarios will shed light on the factors responsible for the increasing rate of energy demand followed by projection of energy trends till 2030 by using two scenarios presented by a LEAP analysis done by Mr. Md Alam Mondal and group (Mondal et al. 2018) in their research paper on 'Ethiopian energy status and demand scenarios: Prospects to improve energy efficiency and mitigate GHG emissions'. One is the 'Reference' scenario which is business-as-usual, and the other is the 'Alternative' scenario under the government's universal electrification programme.

Hence, different dynamics of socio-technical transition of Ethiopian energy system will be presented after the identification of the actors in all three socio-technical levels (landscape, regime, and niches). Finally, with the help of the findings in chapter 3, the interactions between the different socio-technical levels will be highlighted to understand the dynamics responsible for the energy system transition in Ethiopia. At last, as a part of the conclusion and recommendation, the author will summarize his points of view and suggest some future scope.

Chapter 3: Country Profile

3.1. Ethiopia’s Country Information

3.1.1. General Contrast

Ethiopia is a low-income country in the region of Sub-Saharan Africa. It is situated in the ‘Horn of Africa’ towards east direction (see fig. 14). Ethiopia shares its borders with Eritrea 1,033 km to the north, Kenya 867 km to the south, Sudan 744 km and South Sudan 1,299 km to the west, and in the east with Djibouti 342 km and Somalia 1640 km. The population of the country over 102 million across a landmass of 1.13 square kilometer. After the secession of Eritrea in 1933, Ethiopia became the most populated landlocked country in the world. Addis Ababa is the capital as well as the largest city located almost in the centre of the country. The currency used is called ‘Ethiopian Birr’. The national flag is tri-color of green, yellow and red horizontal stripes with an emblem displaying a star in the centre. (Ethiopia Government Portal 2018)

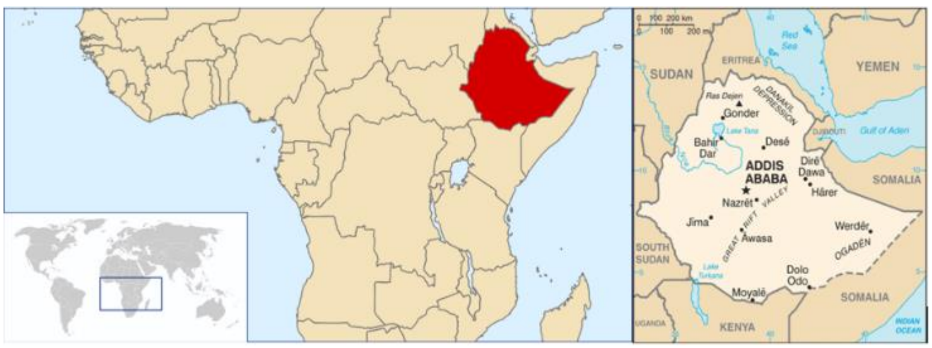

Figure 14: Map of Ethiopia, Source: (Wikimedia 2018)

Figure 15: The regional states of Ethiopia, Source: (BBC News 2005)

There are nine regional states in the federal democratic republic of Ethiopia namely Oromia, Somali, Benishangul-Gumuz, SNNPR, Gambella, Harari, Tigray, Afar, and Amhara and two administrative states namely Addis Ababa and Dire Dawa. The population consists of people from different ethnicity with Oromo 34.4%, Amhara 27%, Somali 6.2%, Tigray 6.1%, Sidama 4%, Gurage 2.5%, Welaita 2.3%, Hadiya 1.7%, Afar 1.7%, Gamo 1.5%, Gedeo 1.3%, Silte 1.3%, Kefficho 1.2%, lastly others 8.8% (see fig. 15). (Britannica Encyclopedia 2018)

Despite being a low-income country, Ethiopia has shown its potential by developing in various sectors making itself one of the top emerging economies in the continent. Although the development is not very high on the scale of achievements, but still better than many other countries similar to Ethiopia. Find some more quick facts and figures about the country in comparison with the world along with a bonus section regarding the country's history, in the annexes.

3.1.2. Geographical Contour

The nation is rich with forest covers, its abundant water resources, the world's hottest settlement of Dallol, and the largest continuous mountain range. Different topological zones ranging from 381 ft below sea level in the Danakil depression to more than 15,000 ft above in the mountain areas. There are high plateau regions located across the land in the west. The Somali plateau is in the direction of the east with arid and rocky semidesert areas spreading out to the Ogaden in the southeastern area of the country. The Danakil desert extends to the Red Sea and the coastal foothills of Eritrea in the north. The western boundary mostly spreads along the high plateau and some regions of Sudan plains. The Blue Nile River originates from Lake Tana which is also the largest lake in Ethiopia. (Ethiopian Government Portal 2018)

There are more than 30 rivers originate from the country in the aforementioned plateau, 14 major rivers flow through the high tableland as well as It has some large water reserves which make the country convenient for hydroelectric power production. (ANDRITZ 2017) A great variety of indigenous plant and animal species are found in the country. Some mountain areas are covered with shrubs and the lakes around the Rift Valley region are blessed with numerous species of birds and overall there are 262 species of birds in the country. Apart from that, there are more than 6,600 species of plants and 277 species of animals. (Ethiopian Government Portal 2018)

3.1.3. Climate and Environment

In Ethiopia, the three important seasons around the year are including climate groups like dry, tropical rainy, and warm temperate rainy climate. The difference between mean maximum and mean minimum temperatures vary sporadically with the max temperature being higher during the period of March-May and the minimum temperature gets lower around in Nov - Dec. Country's highlands have mostly the lowest mean minimum temperatures almost to 0°C from November to January as compared to the higher mean minimum temperature up to 30°C around the areas of Danakil depression. While the mean maximum temperature is mostly around the southeastern and the western lowlands of the country and around Danakil depression the temperature reaches up to 45°C.

The northern regions mostly less rainfall with an annual average mean of about 100mm. Whereas, in the southwestern parts, the average could reach up to 2800 mm. The cycle of wet and rainy seasons hovers around different regions of the country at different times of the year. Regarding the climatic spectrum, Ethiopia has to offer a lot. High temperate to cool highlands, hot arid zones to hot and cool steppes, and tropical Savannah to rainforests are some of the examples. The rainfall happens in two separate seasons. Once during February - March and next during June - September. (Ethiopian Government Portal 2018)

Soil erosion is defined to be a serious issue in the country, particularly around Tigray and border regions with Eritrea. The reasons behind it are ranging from poor agricultural practices, overgrazing, and deforestation. A significant amount of farmland has become vulnerable and to add up to the problems, seasonal problems like severe drought and the civil war which spanned for 17 years have collectively contributed to the country's environmental challenges.

According to the Worldmark encyclopedia, Ethiopia loses 340 square miles of forest land each year due to factors like deforestation and hence leaving the forest resources endangered. As per the latest findings by the Food and Agriculture Organization (FAO), about 12.29 million ha is the total forest cover with other wooded land accounts to 44.64 million ha in Ethiopia as of 2010. (FAO 2010) There were no afforestation and soil conservation programs in practice until the early 1970s in Ethiopia. The three agencies of the government who are responsible for dealing with environmental matters are the Ministry of Agriculture, Forestry and Wildlife Development Authority, and the Ministry of National Water Resources. (Worldmark Encyclopedia of Nations 2007)

The water supply of the country is also at risk as only 11 % rural and 81 % of the urban population enjoy access to safe drinking water. The prime use of the water is for agricultural activities in the country. Under MDGs, Ethiopia did a commendable job by achieving 57 % of safe drinking water access target by increasing the accessibility rate to two folds. Despite this amount of access, the nation's improved sanitation stays as low as 28 % and risks associated with the health and hygiene remains. (USAID 2018c)

3.1.4. Economy

At present, Ethiopia has shown remarkable development and made it the group of fastest developing economies in the world at a growth rate of nearly 11 % per year since 2005. ((Ministry of Finance and Economic Development, MoFED 2013). Along with that, other sectors have experienced the positive growth in the country as well. With all these development experience, Ethiopia still remains as one of the poorest countries in the world. The government wishes to address this situation as soon as possible. Therefore, it has formulated a new set of national goals under its 5-yearly plans called Growth and Transformation Plans (GTPs) in three different phases for the period of 15 years (2010 – 2025) to achieve the goal of becoming a middle-income status country by the year 2025 under the Climate Resilient Green Economy (CRGE) strategy. (USAID 2018b)

A notable trend dictates the structural shift away from traditional and primary sectors and towards secondary and tertiary ones when it comes to sustaining the growth in the country. The same trend holds true for other developing countries as well, for example, the agricultural output decreases with the increase in industrial services and production. (Seid et al. 2015) In the case of Ethiopia, poverty level starts to shrink, and income distribution improves under such trends. The labour markets become the medium of these changes to take place. Lately, the public investments are rising with new numbers which have led the construction business and other industries related with it to flourish. The private sector investment in the country's energy business has been shown a green signal by the government which indeed is a good sign towards development. Three very important factors which have catered to this rapid development in a country like Ethiopia are as follows:

- Investment on Infrastructure and Buildings
- Expansion of employment
- Policy responses

The government under its national planning commission wishes to shift the momentum of the country's economic activities from mostly agriculture towards the manufacturing sector. This will certainly have positive impacts as more durable jobs will be created and sustainable growth can be achieved. (Seid et al. 2015)

The author agrees with the fact that the second phase of Growth and Transformation plans (GTP) which is GTP II spanning from 2016 till 2020 will bring enormous opportunities in the manufacturing sector under new development targets. More information on Ethiopia's 5 yearly Growth and Transformation Plans will be presented in further chapters.

The following figure illustrates the country's steep economic growth over the last decades (see fig. 16). The GDP per capita Ethiopia has reached 549.80 US dollars as of 2017 (see fig. 52, section 4.2.1).

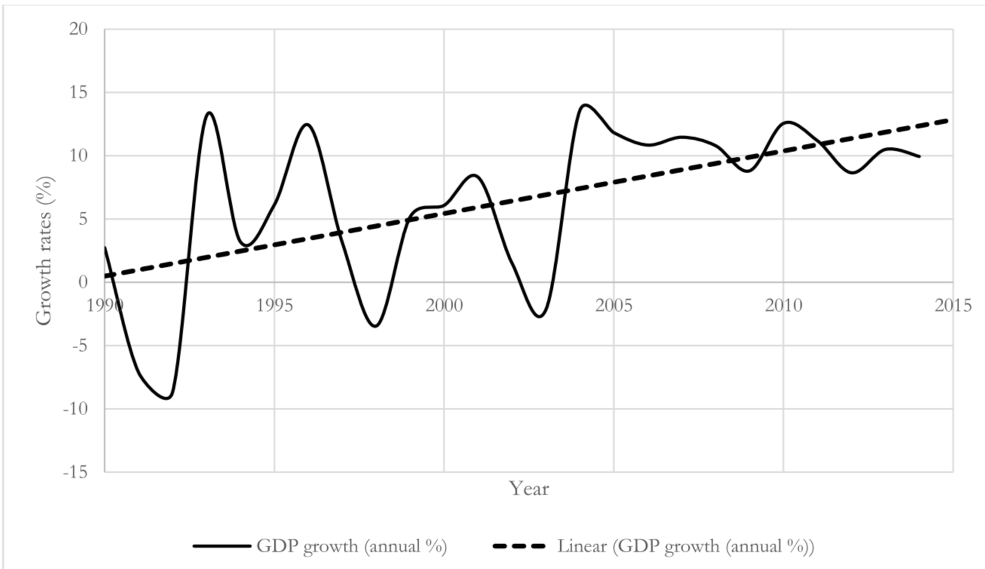

Figure 16: GDP growth in Ethiopia (1990–2014), Source: (Seid et al. 2015)

In addition to the favourable weather conditions for agricultural activities, other factors have equally contributed to the economic growth in Ethiopia. Relevant market reforms were initiated after the new federal government came into power in the 1990s. New policies were implemented towards the development of basic services in the country like buildings, healthcare, roads, infrastructure, telecommunications etc.

The new development vision, activities, and the investments around them were proved to be very important by addressing the critical barriers and enhancing the long-term credibility of the projects in the country. With such drastic development measures taken by the government, Ethiopia could sustain and thrive over the last couple of decades even during the economic recession of 2008 and entered the league of world's fastest growing economies. (Nabli 2011)

3.2. Ethiopia's Energy Portfolio

Energy can be segregated in two categories, namely primary and secondary energy (Eniscuola Energy & Environment 2018) ***primary energy*** is the form of energy which is free to access and exploit from nature without having passed through any man-made conversion process are the primary energy. With the sun being the primary source of energy on the planet, other examples include oil, coal, petroleum, uranium, wood, solar energy, tides, wind, water bodies, and the Earth's heat storage. Some more facts about the country's total primary energy supply are provided in the annex (see table T2, annex).

Primary energy when subjected to conversion technologies become more convenient agents for energy production which otherwise known as energy carriers are called ***secondary sources of energy***, for example, conversion of mechanical energy in hydroelectric plants, chemical energy in thermoelectric stations, or nuclear energy in nuclear power plants. Conversion to electrical power made possible using suitable installations that can convert primary energy into electric energy. The most common energy carriers in today's world are electricity and hydrogen.

Approximately 34 % of Ethiopia's over 102 million inhabitants live below the poverty line. (IEA 2016) Lack of modern sources of energies is very evident in the country. Ethiopia majorly depends on its primary energy supplies accounting mostly to biomass and waste with 91.6% (see fig. 17,18,19). Oil and hydropower follow the race with 6.1 % and 1.7% respectively. The government's ambitious target of becoming a middle-income country by 2025 contains visions in both production and consumption sectors. (Redda 2015) According to African Economic Outlook, Ethiopia is growing rapidly with an average growth of approximately 11% since 2005. (African Economic Outlook 2016)

Ethiopia was the first developing country to submit its Nationally Determined Contribution NDC at the United Nations Framework Convention on Climate Change (UNFCCC) and therefore, shows its commitment to climate challenges. (Irish Aid 2016) By acknowledging the importance of modern energy sources for the country's economic development and improvement of livelihood, Ethiopia is taking steps towards diversifying its energy system and have ambitious goals set. Although its significant economic growth during the last decades have taken initial steps towards industrialization, there is still a heavy reliance on the traditional biomass resources and the trend is also expected to follow in the near future. (Irish Aid 2016)

Despite having massing RE resource potential, the major portion of the country's energy consumption is met from biomass sources. Ethiopia's sectoral energy consumption of biomass energy portrays approximately 92% by households, 3% by services and 1% by agriculture. (Ministry of Water and Energy, Ethiopia 2013a). Biomass energy consumption out of total final consumption accounts to only 0.9 % agricultural and 0.5 % in the industrial sectors respectively. The agricultural sector in rural areas almost entirely relies on muscle power (human and animal) and the use of commercial energy sources like diesel are very limited. The transport sector (accounting to almost 80 % to total consumption) majorly utilizes the petroleum fuels and for cooking and lighting purposes, a smaller share goes to the household sector.

The rest is allocated to the industrial sector for different manufacturing activities. Energy consumption and supply pattern witness a 4.6% decrease in the biomass sector, whereas the share of petroleum fuels and electricity increased from 4.8% to 6% over the years 1996 to 2010. Expected demand for 2030 shows that biomass demand will decrease to 71.6 % while, demand for petroleum and electricity increase to 22.6% and 5.8% respectively. (Ministry of Water and Energy, Ethiopia 2013a)

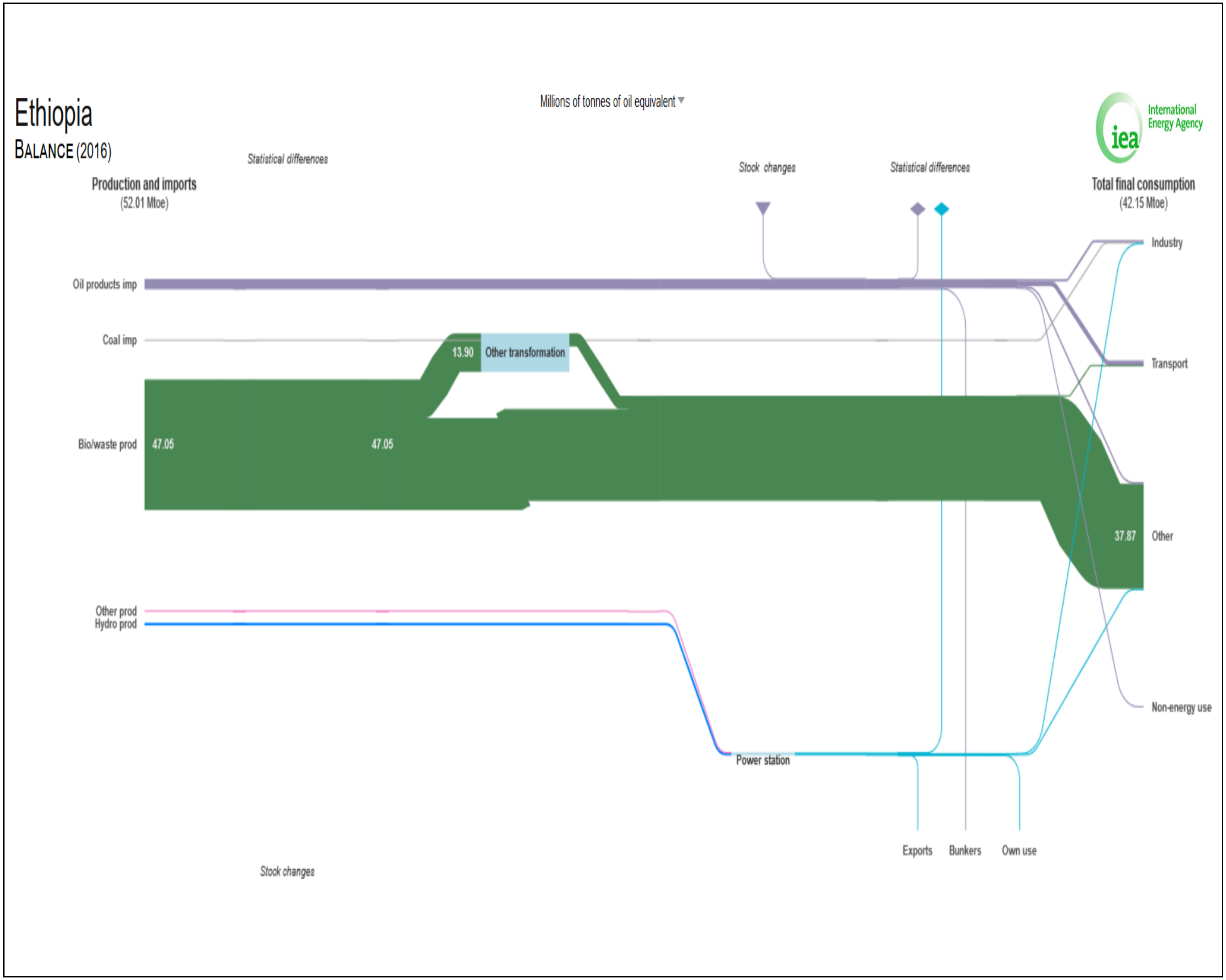

Figure 17: Ethiopia's Energy Balance Sheet, Source: (IEA 2018b)

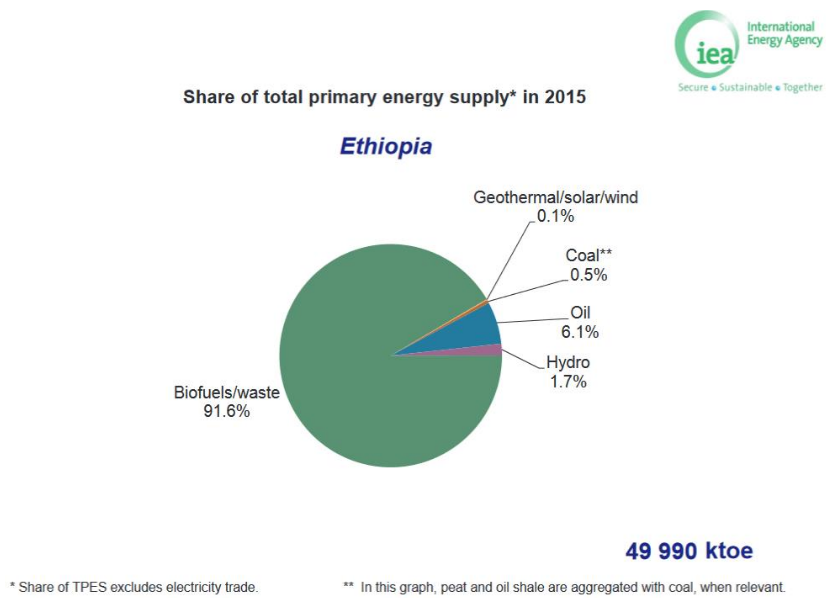

Figure 18: Ethiopia's total energy supply, Source: (Energypedia 2017)

3.2.1. Primary Energy Sector

From the chapters above, it is known that how rich Ethiopia is in terms of inland natural resources. Apart from natural asphalt which is used for roads construction. The biomass is accounted for over 91% of energy source (see fig. 18,19). However, one important factor to pay attention is that together with electricity, the petroleum supplies which accounts for about 7% of total primary energy are equivalent to only 2 % of total energy use in Ethiopia. (Mondal et al. 2018) The rest 98% goes into the share of biomass consumption. The predominant sources of biomass available and being used in the country are drawn from inland resources like firewood, crop residues, and dung. Wood is the most common biofuel which is used to meet the heating and cooking demands in households in Ethiopia. About 81% of the estimated 16 million households use firewood, 11.5 % use leaves and dung cakes, while only 2.4 % use kerosene for cooking. (Ministry of Water and Energy, Ethiopia 2013a)

However, because of the lack of alternatives and increasing population growth, wood fuel is being overused and overconsumed which creates a lot of pressure in the natural environment. The rate of natural reproduction of wood does not cover the annual demand for wood which is approximately around 37 million tonnes. (Ministry of Water and Energy, Ethiopia 2013b)

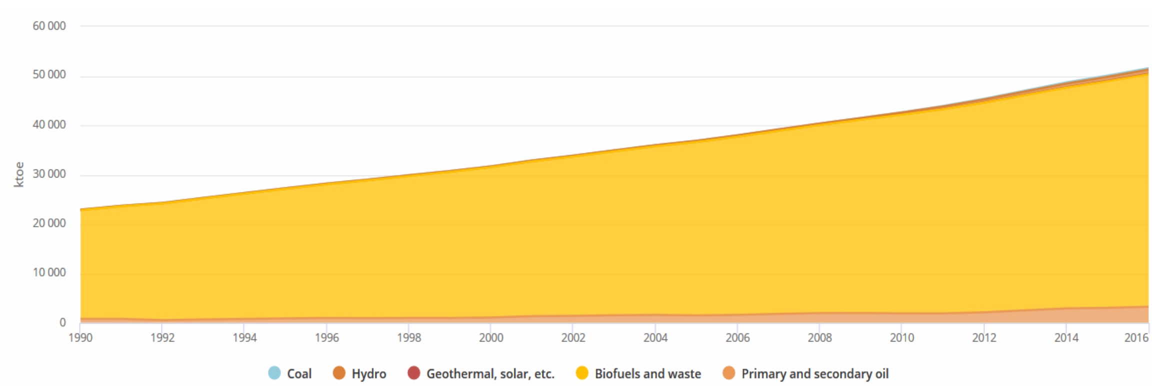

Figure 19: Total primary energy supply by source, Source: (IEA 2018a)

3.2.2. Secondary Energy Sector

It is a worldwide trend to replace primary energy through secondary energy to decrease the direct impact on the environment. Ethiopia follows the same trend as well by trying to improve the energy production by secondary energy sources, also called as energy carriers. The secondary energy is produced from the primary energy sources through the man-made conversion process. Solar, hydro, wind energy conversions are important examples of the same. Three main secondary energy entities in Ethiopia are presented as follows and the energy stats over the time has been compiled from IEA data. (see table 2). Total energy supply statistics are provided in the annex (see Table T3, annex).

- Electricity
- Bio-fuel
- Refined oil products

Table 2: Ethiopia's key energy stats, Source: Raw data from (IEA 2018a), Own compilation

	GDP	Energy production	Net energy imports	Total primary energy supply	Electricity consumption	CO2 emissions	Population
	billion 2010 USD	Mtoe	Mtoe	Mtoe	TWh	Mt of CO2	Million people
2000	13.08	30.6	1.1	31.69	1.51	3.2	66.54
2002	14.38	32.44	1.25	33.86	1.84	4.04	70.5
2004	15.97	34.37	1.41	35.98	2.29	4.8	74.62
2006	19.8	36.37	1.75	37.98	2.94	4.8	78.85
2008	24.44	38.4	2.18	40.38	3.29	6.27	83.19
2010	29.93	40.7	2.26	42.63	3.99	5.98	87.7
2012	36.16	43.11	2.6	45.34	5.52	7.29	92.44
2014	44.09	45.52	3.5	48.64	6.95	10.13	97.37
2016	52.35	48.01	3.99	51.54	9.14	10.93	102.40
Growth % (2000 – 16)	300%	57%	263%	63%	505%	242%	54%

3.2.2.1. Electricity

As of 2018, around 42% (23 % in 2013) of the total population had access to electricity. (Trading Economics and World Bank 2018) With the urban sector having 85.4 % (85 % in 2013) and rural sector having only 26.5 % (10 % in 2012) electricity access, the gap is still pretty huge to cover. (World Bank 2015). 83 % of the total population in Ethiopia is rural based and the settlements are heavily dependent on traditional biomass resources to meet their energy demands which majorly are cooking and heating. Electricity, however, was mostly presumed to be as an urban commodity until recent past with households and industries alike. According to the ministry stats, electricity consumption was about 2,400 GWh, which 33% is by households, 40% by industries and 27% by service sector as of 2013. (Ministry of Water and Energy, Ethiopia 2013a)

The per capita electricity consumption as of 2016 was 90 kWh which is still way below the average level of per capita energy consumption across other African nations. (Tessema et al. 2014 and IEA 2016) In November 2017, under its new policies and regulations, Ethiopia has launched the 'Light to All' *National Electrification Program (NEP) with the goal of offering "equitable and affordable electricity to all Ethiopians by 2025"*. (Ministry of Water, Irrigation, and Electricity 2017)

Since the government aspires to diversify the national energy mix, currently the production of electricity in the country is from a mix of affordable and clean primary energy sources. Hydropower being the most prominent source and to top it up, the recent development in wind sector bolster the energy mix of the country shows the commitment of the government. The graphs below show the share of electricity generation (by different fuels) and consumption patterns over the past few decades. (see fig. 20,21). (IEA 2018a) Some key stats related to the electricity sector as of 2014 are listed in the annex (see table T2, Annex). (AFREC 2015)

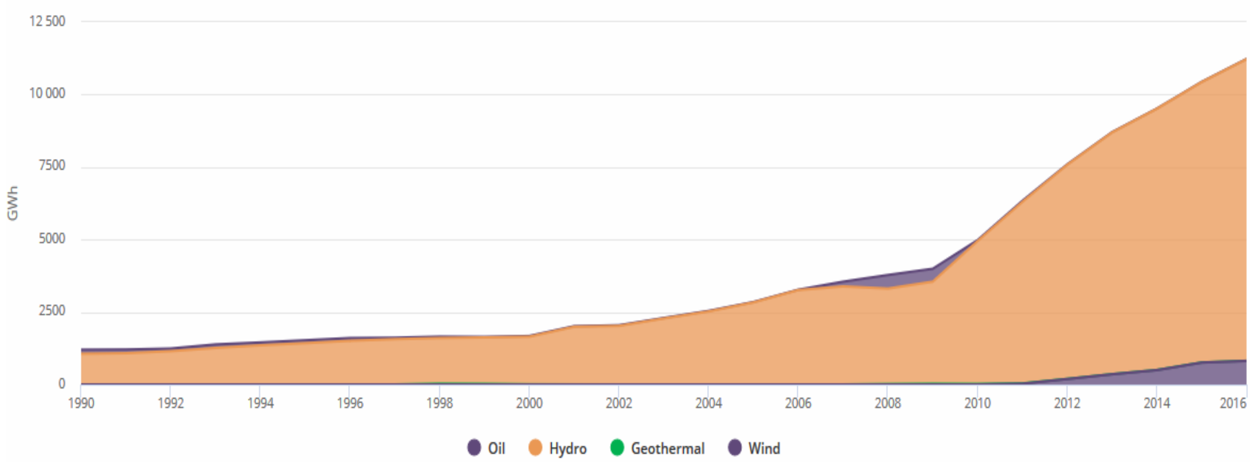

Figure 20: Electricity generation by fuel, Source: (IEA 2018a)

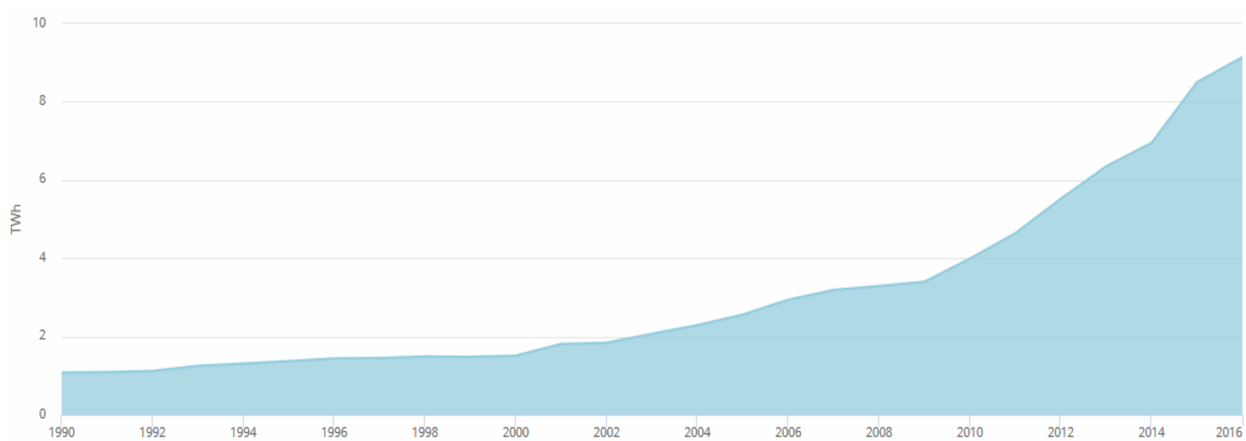

Figure 21: Total electricity consumption, Source: (IEA 2018a)

In the electricity sector, the transmission lines and batteries are known to be the important energy carriers or medium for transportation of electricity. However, due to the uneven geographical contour, the transmission lines are not so well spread in the country. Total electrical demand in Ethiopia is expected to increase by around 30 % annually according to the government's study. (USAID 2018a) After the commissioning of Gilgel Gibe III power plant, it contributes additional 1870 MW to the national power grid by increasing the installed generation capacity to almost 4.3 GW. However, the lack of substations and power transmission lines have emerged as the major shortcomings to be addressed immediately. Consequently, several dams are not operating at their full capacity due to the lack of transmission lines for the electricity to be transported to the consumers. (AFD 2016)

The share of electricity access and consumption have increased dramatically since the beginning of the millennium (see fig. 21). (IEA 2018a) Based on the national Growth and Transformation Plans, the government aims to double the proportion of the population with electricity access through the expansion of the national grid and decentralized rural electrification strategies. As a result, the government predicts the rate of rural electrification to grow by 10 % and 20 %, by the years 2020 and 2030 respectively. The urban electrification rate is assumed to increase to 90% by 2020 and to 95% by 2030. There are new projects planned and in progress under Growth and Transformation Plans (GTPs) to upgrade and expand the electricity sector. The tables below present the upcoming projects per sector and transmission lines expansion both nationally and with neighbouring countries (see fig. 22, table 3,4). Followed by that, a comprehensive targets compilation under the GTP II is illustrated (see table 5).

Table 3: Upcoming project capacity targets under GTP II, Source: (EEP 2015)

Resource	Capacity (MW)
Hydro	11,015
Wind	1,520
Geothermal	1,270
Solar	300
Biomass	420
Total	14,615

Table 4: Upcoming transmission lines expansion targets under GTP II, Source: (EEP 2015)

Transmission Lines (KV)	Distance (km)
500	1,229
400	2,137
230	3,343
132	3,041
< 132	250
Total	10,000

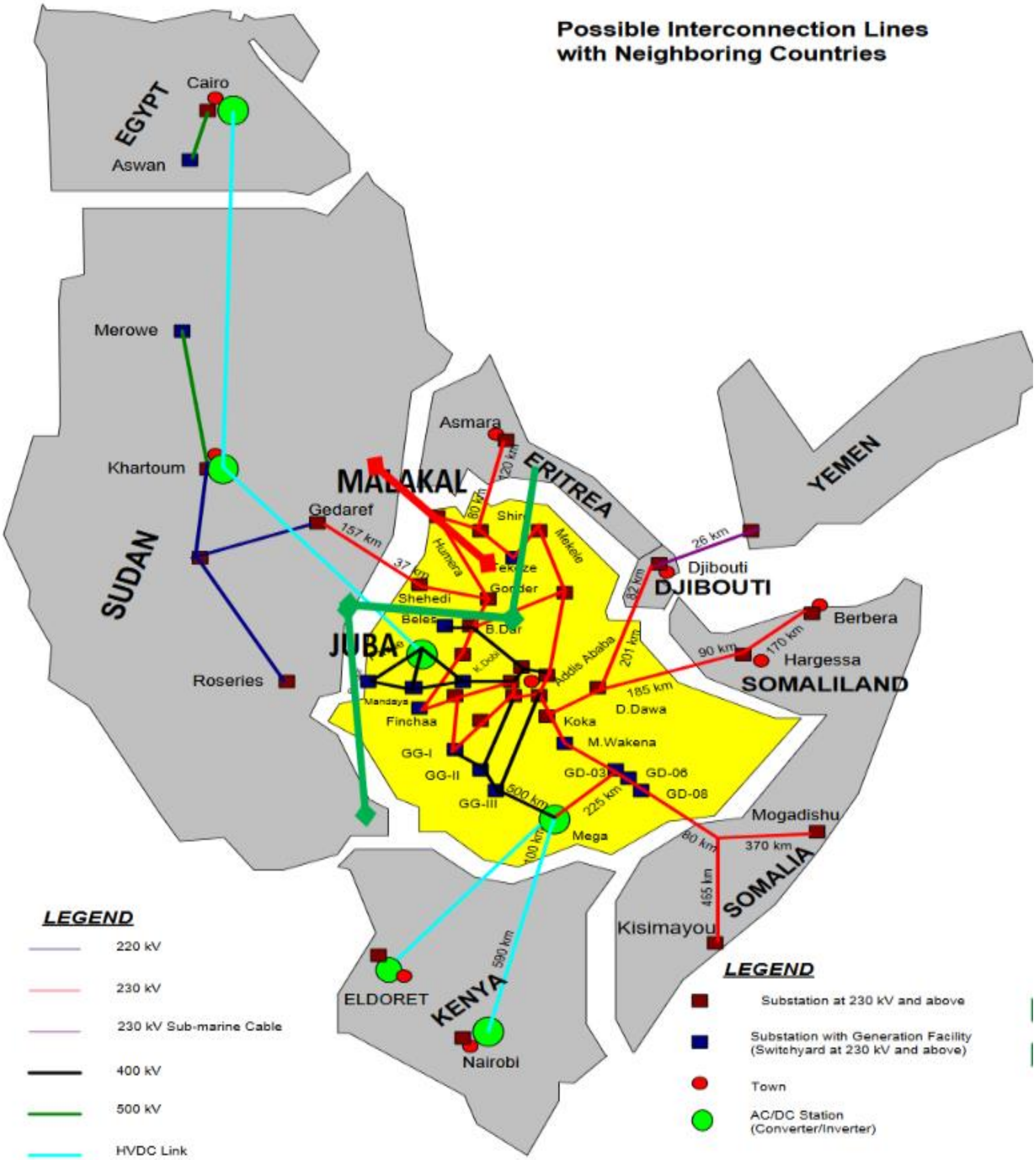

Figure 22: Ethiopia's transmission lines expansion plan under GTP II, Source: (EEP 2015)

Table 5: Targets under GTP II of Ethiopia, Source: (EEP 2015)

No.	RE Source	Project	Installed Capacity (MW)	Energy (GWh)	Indicative Cost (MUSD)	Planned Year of Completion
1	HYDRO	Geba I & II	372	1709	572	2020
2		Genale Dawa VI	256	1532	588	2020
3		Werabesa + Halele	422	1973	886	2020
4		Yeda 1 + Yeda 2	280	1089	540	2020
5		Gibe IV	2000	6200	2000	2020
6		Tams	1700	5760	4214	2020
7		Upper Dabus	326	1460	628	2020
8		Wabi Shebele	88	691	1100	2020
9		Karadobi	1600	7857	2576	2021
10		Beko Abo	935	6632	1260	2022
11		Upper Mendaya	1700	8582	2436	2023
12		Birbir River	467	2724	1231	2023
13		Baro 1 + Baro 2 + Genji	859	3524	1794	2024
14		Genale V	100	575	298	2025
		Total	**11,105**	**50,308**	**20,123**	
1	Wind	Iteya I	200	613	380	2016
2		Iteya II	200	312	420	2016
3		Dila	100	306	210	2018
4		Iteya II	200	613	380	2017
5		Assela	100	307	190	2018
6		Debire Birihan	100	613	380	2017
7		Ayisha I & II	420	1577	760	2017
8		Sululta	100	306	210	2019
9		Mega Maji	100	306	210	2019
		Total	**1520**	**4955**	**3140**	
1	Solar	Different Sites	100	175	180	2016
2			100	175	180	2016
3			100	175	180	2016
		Total	**300**	**525**	**540**	
1	Geothermal	Corbetti	1000	7096	4000	2017 - 2022
2		Aluto Langano II	70	552	280	2018
3		Aluto Langano III	100	788	364	2017
4		Tendaho	100	788	364	2016
		Total	**1270**	**9224**	**5008**	
1	**Biomass**	**Any Resourceful site**	**420**	**2940**	**525**	2009
		Grand Total	**14,615**	**67,427**	**23,624**	

3.2.2.2. Bio-Fuel

The national foreign currency reserve is eroding because of the rising oil import costs. Along with that, rural poverty alleviation and national energy security are the matters of great concern. These factors managed to draw the attention of the government towards the development of biodiesel as an alternative to imported oil since last few years. (Nadew Tadele 2014) The government inaugurated its first extensive bio-fuels expansion strategy and started promoting investments in this sector in 2007.

Since then, they have promptly managed to attract many local and international private investors in the country. The government has basically supported two biodiesel crops namely 'Jatropha' and 'Caster'. The reason for these crops being widely promoted are their ability to grow on marginal soil even in a drought like conditions to become the perfect feedstock for biodiesel production. The oil from the seeds could either directly be fed to internal combustion engines or can be further processed to obtain biodiesel. The leftovers could further be used as bio-briquettes to be used as solid biomass fuel. (Negash and Riera 2014)

Sugar factories play an important role in Ethiopia by producing biodiesel and ethanol. The process states that the conversion of sugarcanes into useful sugar and use the residues (sugar molasses) for manufacturing bioethanol. The cogeneration units of the sugar factories in the country produce bio-ethanol quite efficiently as the bio-ethanol production process is not a very energy-consuming method, therefore, their favorability rate is high. (Ethiopian Sugar Corporation 2017). In 2017, The annual bioethanol production capacity was at 103,000 m^3 and it is expected that the production capacity will be tripled by the year 2020 with the planned policies and commissioning of new capacities.

Ethiopia also has an ongoing program of blending fuels. With the biofuels development being prioritized as one of the prime agendas in the country's national policy, the government has created provisions for blending ethanol with gasoline for cooking purposes. On the other hand, fuel blending techniques are also used in the transport sector. These measures are taken to address the alarmingly growing demand for imported petroleum products and to curb on the harmful emissions. (Nadew Tadele 2014) E10/Gasohol is mandatory in Ethiopia as the bio-ethanol is produced on a large scale which is sufficient to blend with imported gasoline. (Abiye 2011) As of August 2015, Ethiopia had blended about 59.6 million liters of ethanol since 2010, saving 46.9 million USD of imported oil. (Meghan Sapp 2015)

3.2.2.3. Refined oil products

The most important refined oil product Ethiopia uses is diesel fuel and its share is 20.1 TWh out of 37.3 TWh refined oil products that Ethiopia acquires as of 2018. As mentioned in the previous chapters that the transmission lines are not spread evenly throughout the whole country which poses a challenge for access to electricity. Diesel fuel is used in such areas to power up the generators to meet the electricity demand in both private and public sector. Such systems are categorized under self-contained or independent systems to meet the immediate electricity demands locally.

Apart from that, the major utilization of diesel is in the thermal power plants for electricity generation. Road transportation, especially the trucking, also depends majorly on the refined fuel like diesel and the demand is increasing on a huge scale since Ethiopia is taking strides towards development and together with that the transportation of goods both nationally and across the borders are also seeing new heights. The following graph shows the oil consumption in the country during the last few decades (see fig. 23). (IEA 2018a)

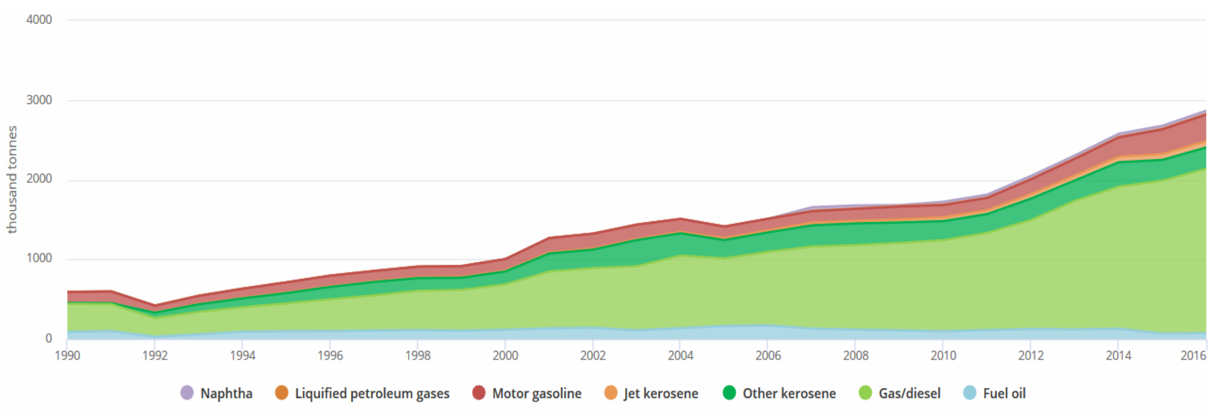

Figure 23: Ethiopia - Oil Consumption, Source: (IEA 2018a)

Along with diesel, kerosene is also considered as equally important fuel used in Ethiopia mostly for lighting and cooking purposes in the rural areas as electricity access is not all over the country. The share of kerosene in the total oil share of the country is about 8.8 TWh. (UN Data 2015) 3.1 TWh is used in households, whereas the rest 5.7 TWh of the share is used by Ethiopian Airlines (the national carrier) as aviation kerosene for the turbines in the aircraft. (Total 2018)

3.2.3. Energy Demand Scenarios

The population growth, economic activities, electrification scales, energy consumption patterns and practices, and consumer behaviour are the factors essential for understanding the past trend of energy demand and assess how it is going to be in the future. Along with that, the energy policies and their upgradation also play a vital role in setting a trend in the energy sector. This chapter will describe the energy demand with respect to the work of LEAP analysis done for Ethiopia by Mr. Md Alam Mondal and group. A Long-range Energy Alternative Planning (LEAP) analysis describes the scenario as follows. Two scenarios are taken into consideration for this assessment. One was 'Reference' scenario which is stating the obvious trend of the society based on the historical data on population, GDP growth, and other above-mentioned essential factors and the assumption is that historical trends will continue similarly into the future. Whereas, the alternative scenario is developed in line with government goals within three cases namely universal electrification, improved cookstoves, and efficient lighting.

This section begins with the reference scenario to better understand the current situation based on business-as-usual conditions. 2012 is considered as the base year for this study and the trend will follow till 2030. Followed by that, the focus shifts to the alternative scenarios which fall under the top priorities of the government. During the years 2012-14, the country's primary energy sources were biomass, which accounted for about 91% of energy consumption. 7 % came from petroleum supplies and electricity was accounted for only 2% of total energy use. Residential sector in biomass consumption claimed over 98% out of net supply in the country. (Mondal et al. 2018) With respect to per capita emissions, those shares amounted to 0.06, 0.075, and 0.19 tons of CO_2 in 2005, 2010, and 2014 respectively. (World Bank 2015)

In the table below, the potential of different energy resources in the country and their share of exploitation as of 2016 is observed (see table 6) as per the data from Ethiopian Electric Power (EEP). Another very interesting graph (see fig. 24) shows the historical trend (1980 - 2010) of energy consumption and production patterns along with the energy security to have an image of the past progression. (G. Ramakrishna 2015)

One important thing to notice there is the line of energy security being mostly flat throughout the time which indicates towards the low averages of energy access to the citizens. Normally, the energy demand increases rapidly with good economic growth and it holds true in the case of Ethiopia as well. The prospective energy demand depends on many factors like the country's GDP, population growth, the rate of urbanization, industrialization, the cost associated with fuels, infrastructure development and so on. However, (Senshaw 2014) points out that the lack of alternatives and poor performance in energy efficiency measures are also the causes contributing to Ethiopia's escalating energy demand.

Table 6: Resources potential and their exploitation share, Source: (EEP 2015)

Resource		Unit	Exploitable Reserve	Exploited Percent
Hydropower		MW	45000	< 5%
Solar		kWh/m^2	4 – 6	< 1%
Wind	**Power**	GW	100	< 1%
	Speed	m/s	> 7	
Geothermal		MW	< 10000	< 1%
Wood		Million tons	1120	50%
Agricultural Residue		Million tons	15 - 20	30%
Natural Gas		Billon m^3	113	0%
Coal		Million tons	300	0%
Oil Shale		Million tons	253	0%

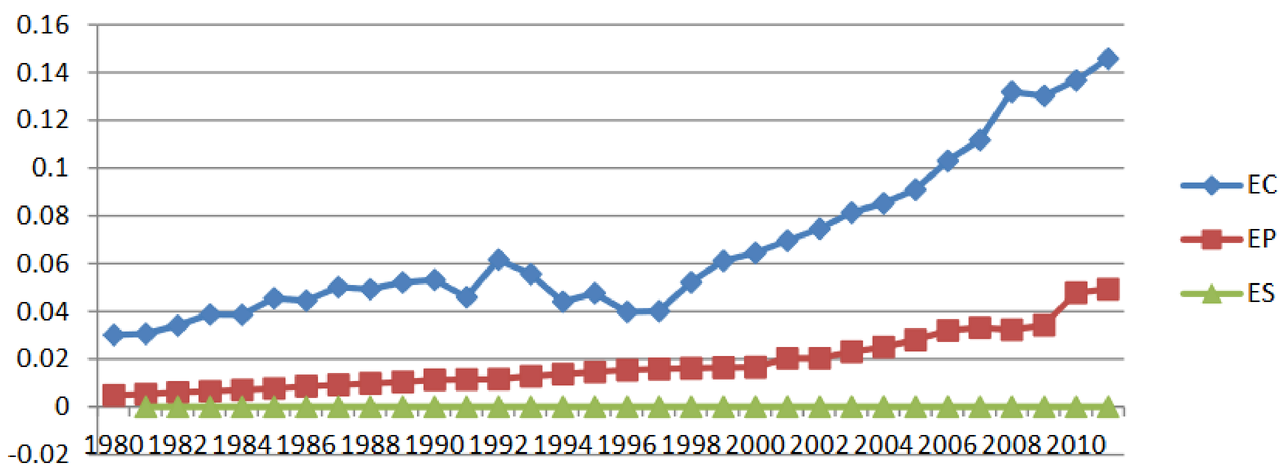

Figure 24: Energy Consumption, Production and Energy Security, Source: (G. Ramakrishna 2015)

3.2.3.1. Reference Scenario

By 2030, Ethiopia's population is predicted to increase to around 129 million. (Demographic Divident 2016) As per the ministry, 21% of the total population is expected to live in urban regions. (Ministry of Water and Energy, Ethiopia 2013a) In 2011, 4.6 was the average household size in the country. which is marginally lower than the 2005 average of 5.0 members. There are less members in urban households averaging to 3.7 members as compared to the rural average of 4.9 members. In long term, this continuous population growth rate declination and increasing urbanization rate assume the average household size to decrease to 4.4 members by 2030 in Ethiopia. (The World Bank 2016a) In the previous 'Electricity' section, the government's motive was presented regarding rural and urban electrification targets. Rural electrification grows by 10 % in 2020 and 20 % in 2030 and urban electrification grows to 90 % in 2020 and 95 % by 2030 as per the government's prediction.

There has been an increment in the rate to use of appliances. It is expected that television will be owned by 60% of urban households and 20% of rural households and refrigerators by 30% of urban households and 10% of rural households by 2030. Basically, on an average, the electrical appliances use about 160 kWh in urban households and 110 kWh in rural households annually. (Mondal et al. 2018) The share of the population with access to electricity has increased dramatically from 12.9% in 2006 to 42% in 2018 (23 % in 2013). (World Bank 2018a) The latest figures on electricity access rate account for 85.4 % in urban areas, but still much lower in rural areas at about 26.5% in 2018 (from 10 % in 2012). (Trading Economics and World Bank 2018)

The country's Growth and Transformation Plan (GTP) also outlines the necessity and importance of energy conservation and energy efficiency and therefore, it has corresponded that about 11 million efficient lamps have already been introduced in the country in lighting to replace incandescent bulbs. (Hilawe and Xavier 2013) Based on the above fact, it is estimated that about 25% of electrified households have access to these efficient lamps. It is also expected that the usage rate of compact fluorescent lamps (CFL) and efficient tube lamps will increase to 20% in 2020 and 30% in 2030 respectively. When it comes to the consumption pattern in a rural and urban setting, it has been seen that urban electrified households consume an average of 231 kWh (kWh) per year and rural households consume an average of 168 kWh according to the energy balance sheets. (Mondal et al. 2018) The light rail service which started in 2015 were also considered in the reference scenario in the projections from the government reports regarding electricity demand in the future.

Based on the energy balance sheets developed by the Ministry of Water, Irrigation and Energy, the Report on the Ethiopian Economy, Ethiopian Biomass Energy Strategy Action Plan, and the IEA's Energy Balance for Ethiopia, the household energy consumption in rural and urban environments is estimated to be different from each other. The table below displays the share of individual fuel use for cooking purposes (see table 7, fig. 25). (The World Bank 2016a) The first four columns in table 7 show the current practices of cooking fuel consumption rates whereas, the last four columns display the rates extrapolated to the future based on the data from the current trend under reference scenario.

Table 7: Percentage share of fuel use for cooking (%), Source: (Mondal et al. 2018)

Fuel/Sector	2004		2012		2020		2030	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Electricity	2.4	0.1	6.1	0.0	10	1.5	15	6
Kerosene	13.8	0.2	4.9	0.2	4	0.5	3	1
Butane	2.4	0.1	1.1	0.0	1.2	0.05	1	0.5
Firewood	65.3	84.5	63.3	90.9	60	89	55	82
Charcoal	7.7	0.2	17.5	0.2	20	2.5	24	5
Agricultural Residue	8.5	15.0	7.0	8.0	4.8	6.45	2	5.5

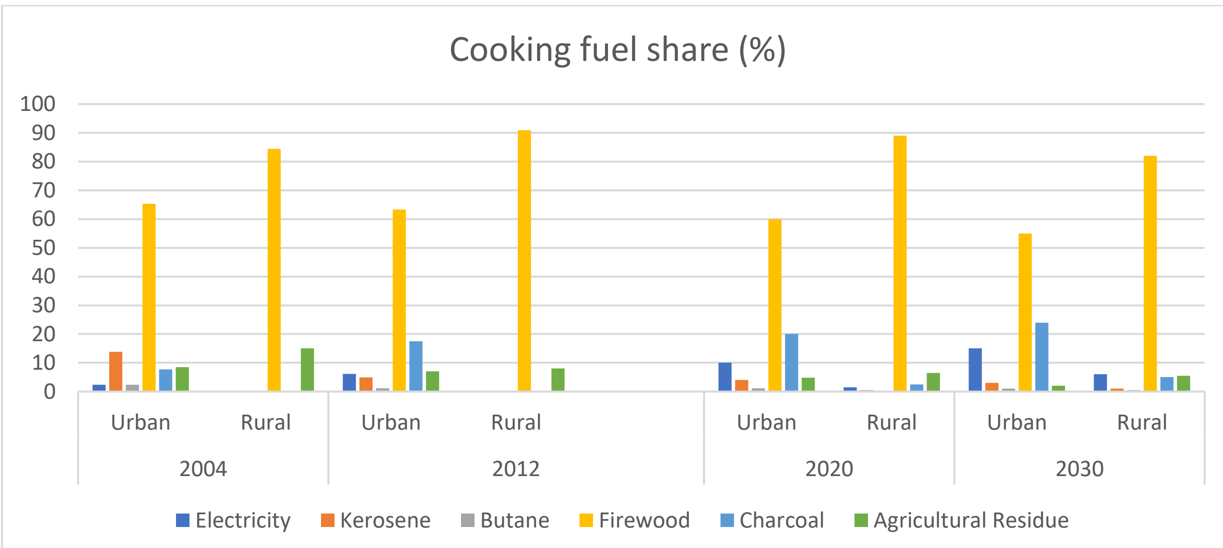

Figure 25: Percentage share of fuel use for cooking, Source: Own illustration based on data from (Mondal et al. 2018)

On average, the firewood consumption claims about 4600 kg/year in rural households which is higher as compared to the average of 3400 kg/year in urban households. This translates to the heavy reliance of the rural sector on traditional biomass. The rural residents mostly use firewood for cooking purposes (91%) and a few portions opt for other cooking fuels like charcoal (5%) and agricultural leftovers (4%). (Mondal et al. 2018) Although other fuels like charcoal usage have seen increments over the last couple of years, still they are not significantly adopted everywhere as most rural households cannot afford to purchase charcoal and biomass energy resources like branches, leaves, and twigs (BLTs) are freely available in nature. (Yurnaidi and Kim 2018)

Based on the historical trends and given the importance of firewood in rural areas, the reference scenario assumes that firewood use will decline only slightly to 89% in 2020 and 82% in 2030, while charcoal use is expected to increase marginally to 2.5% in 2020 and 5% in 2030. (Mondal et al. 2018) Since firewood is the most preferred energy source in Ethiopian energy portfolio and is also expected to remain in times to come, the government takes the efficiency measures seriously to reduce demand for firewood and hence have introduced about 5 million efficient cookstoves in the country.

Improved cookstoves not only save a lot of energy consumption by efficiently using the available fuel but also check on indoor pollution. However, the efficiency of the cookstoves depends on their quality and fuel use. Various studies demonstrate that the energy saving potential of efficient cookstoves in comparison with traditional stoves varies from 20% to 67%. (Hilawe and Xavier 2013)

On the other hand, urban households rely on a wider range of cooking fuel sources, such as electricity, kerosene and charcoal, and only 63% still dependent on firewood at the moment. Fuelwood is still expected to cover the largest share at 79.9% of total energy demand in the country by 2030. Reports from the World Bank and the government show that GDP has increased from USD 9.1 billion in 2000 to USD 25.1 billion in 2012 with a remarkable growth rate. In Ethiopia, as of 2012, agriculture and service sectors accounted for 43 % and 46 % of GDP shares, while industry remained at only 11%. The data show the declining trend in the share of GDP from the agricultural sector since 2000, while the service sector is flourishing. On top of that, with the Growth and Transformation Plans (GTPs) in force, the GDP is very likely to keep up with its pace at a rate of more than nearly 11 % during 2010 - 2015, 11% during 2015 - 2020, and 10.5% during 2020 - 2030. (Mondal et al. 2018)

3.2.3.2. Alternative Scenarios

Three alternative cases were selected as they were identified by the government as important milestones in several strategy documents including the Growth and Transformation Plans (GTPs), Rapid Assessment and Gap Analysis Report by SEforALL, and Ethiopia's Climate-Resilient Green Economy Strategy and so on. They define the necessity of enhancing energy efficiency measures, energy access amplification and decreasing the level of harmful emissions from the energy sector in Ethiopia. (Hilawe and Xavier 2013) Three alternative scenarios have been considered for the study and comparison with the reference scenario and the comparisons between the assumptions rates in both reference and alternative scenarios are presented in the next section:

- The universal improved cookstoves
- The efficient lighting
- The universal electrification

The **universal improved cookstoves** scenario is focused on the objectives of energy saving and GHG mitigation. It is established in the reference scenario that firewood will still be the preferred cooking fuel of the future. Therefore, significant efficiency measures can be the key to check on this rising by means of penetration of improved cookstoves. Regarding the quality of the improved cookstoves (Mondal et al. 2018) noted that the saving potential of improved cookstoves ranges from 20 % to 67 % when compared to normal cookstoves. An increased entry of improved cookstoves is assumed to be 80 % in the electrified urban households, 70 % in the unelectrified urban households, 50 % in the electrified rural households, and 40 % in the unelectrified rural households by the year 2020. By 2030, these diffusion rates are assumed to increase by 100 %, 90 %, 80 %, and 70% respectively. An eventual increment of 10 % by 2030 in the efficiency of existing cookstoves has been also taken into consideration in this scenario. (Mondal et al. 2018)

The **efficient lighting** scenario takes a more rapid diffusion rate of efficient lighting units like compact fluorescent lights (CFL) and tube lamps into consideration which are 70 % and 30 % more efficient than incandescent bulbs respectively. (Jason Steele 2018) Faster adoption of efficient lighting units will result in a considerable amount of power saving.

The estimated increase in the use of CFL is 20 % by 2020 and 40 % by 2030, whereas for tube lamps it increases to 30 % by 2020 and 60 % by 2030 in the households of Ethiopia. The assumption in this scenario contains a 50 % decline in the use of incandescent bulbs by 2020 completely terminates by 2030. It is established in the reference scenario that the consumption patterns for lighting in the urban and rural household are different and influence the total energy savings greatly. Therefore, the transition to more improved lighting units and their diffusion in Ethiopian households will be the highlight of this efficient lighting scenario. (Mondal et al. 2018)

Now, considering the **universal electrification** scenario to project the development and compare it with the reference scenario. A more rapid expansion of electricity access as compared to the reference scenario through the national grid is assumed in this scenario. The rural electricity access is expected to expand by 50 % and 100 % by the year 2020 and 2030, respectively, whereas for the urban sector these increments state 95% and 100% of expansion by the year 2020 and 2030, respectively. On top of that, accelerated urbanization is assumed at a rate of 30% by 2030. (Mondal et al. 2018)

3.2.3.3. Comparison between Reference and Alternative Scenarios

The reference scenario provided a baseline standpoint to assume the changes in future with the case of historical trend and case of alternative scenarios. The results of LEAP analysis by Mr. Md Alam Mondal and group pointed out that the energy demand will increase throughout all the sectors by the year 2030 and presented the following results for reference scenario.

Results from 'Reference' scenario

The expected increase in the total energy demand is from 1358 PJ in 2012 to about 2120 PJ in 2030 with the largest share of demand coming from industrial sector at a rate of 11.6 % per year as the country is developing with a goal of becoming a middle-income status country by 2025 and pushing for more industrial activities in the country. Agriculture, transport, and services and others follow the line in terms of demand (see table 8). The figure below shows the energy consumption per sector. (see fig. 26).

Table 8: Energy demand per sector (PJ), Source: (Mondal et al. 2018)

Sector/Year	2012	2015	2020	2025	2030	2012 – 30
						Ann. Avg. growth (%)
Household	1340.0	1343.2	1422.0	1574.3	1796.4	1.6
Agriculture	14.1	17.4	19.7	28.4	30.1	4.3
Services and others	15.4	18.0	18.7	26.0	24.8	2.7
Industry	15.8	31.4	45.7	80.3	113.1	11.6
Transport	73.0	92.5	127.2	141.2	155.3	4.3
Total	1458.3	1502.6	1633.3	1850.3	2119.8	2.1

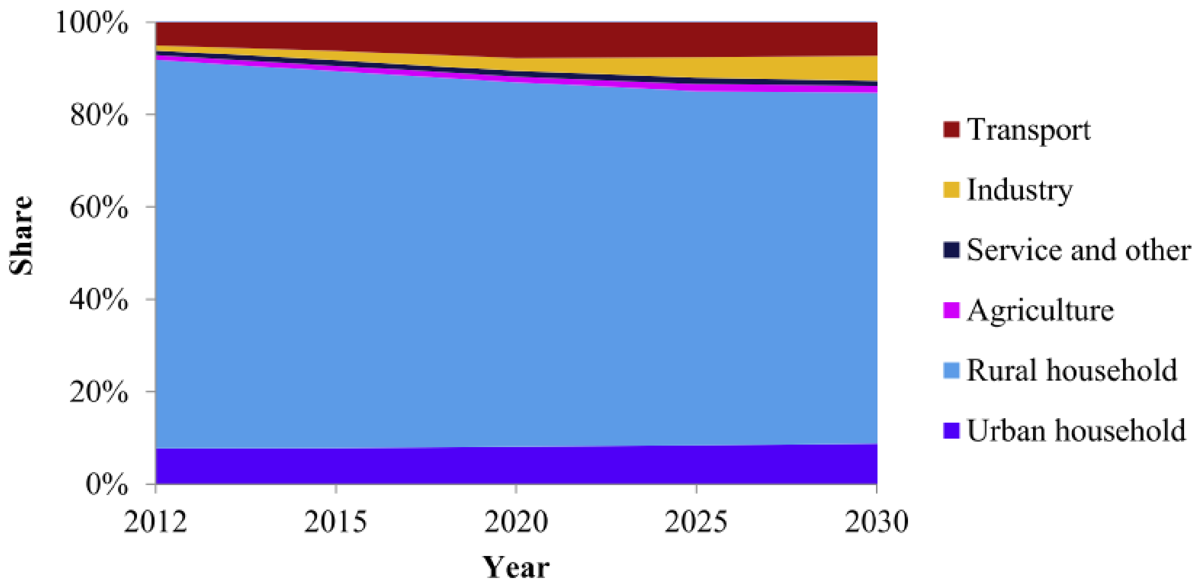

Figure 26: Sector-wise energy consumption under the reference scenario, Source: (Mondal et al. 2018)

The analysis also showcases that the household sector will also witness an increase in the energy demand from 1340 PJ to 1796 PJ during the period 2012 – 2030. This less growth rate even though with the largest demand share indicates the saturation in the household sector as the government's GTP goals translate to 100 % electrification by the year 2025. The residential sub-sectors demand trends are presented in the table below for different types of fuel (see table 9). It shows that the rural sector will still rely on a greater share of wood until 2030. The other fuels like electricity, charcoal, and LPG are expecting massing increasing in their demand at 9.1 %, 16.8 %, and 17.5 % respectively by 2030. Likewise, in urban sector wood demand almost remain constant with the considerable increase in the electricity demand of 7 %. Overall, there is a 7.6 % growth rate of the energy demand in the residential sector. Regarding the total energy demand in Ethiopia by different sources of fuel during the period of 2012 – 2030, demands for some fuel sources will increase over time. The projections illustrate that for fuels like oil, electricity, LPG, charcoal, gasoline, and fuelwood will see growth at a rate of 11.3 %, 9.7 %, and 8.3 % respectively in future (see table 10).

Table 9: Energy demand by urban and rural household in the unit of Petajoules (PJ), Source: (Mondal et al. 2018)

Fuel/Sector	2012		2020		2030		2012 – 30 Ann. avg. growth (%)	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Electricity	4.2	1.5	6.7	2.6	14.3	7.2	7.0	9.1
Kerosene	0.3	5.9	0.4	6.6	0.4	8.7	1.2	2.2
LPG	0.1	0.0	0.1	0.0	0.1	0.2	3.2	17.5
Wood	99.2	1172.6	113.8	1220.4	155.2	1514.0	2.5	1.4
Charcoal	5.9	0.3	8.4	0.9	15.6	4.2	5.5	16.8
Biomass	2.4	47.6	2.3	59.9	1.5	75.2	-2.8	2.6
Total	112.1	1227.9	131.6	1290.4	187.0	1609.4	2.9	1.5

Table 10: Total energy demand by different fuel sources in the unit of Petajoules (PJ), Source: (Mondal et al. 2018)

Fuels/Year	2012	2015	2020	2025	2030	2012 - 30 Ann. Avg. growth (%)
Electricity	15.1	24.2	34.1	56.4	80.0	9.7
Gasoline	23.4	33.2	50.1	58.5	66.6	6.0
Kerosene	6.2	6.4	7.0	7.9	9.1	2.2
Diesel	59.8	75.3	98.7	119.5	137.5	4.7
LPG	0.1	0.1	0.1	0.2	0.3	8.3
Oil*	3.8	7.5	10.8	18.7	25.8	11.3
Wood	1284.0	1284.3	1350.8	1493.9	1693.2	1.6
Charcoal	6.2	7.1	9.2	13.5	19.7	6.7
Biomass	59.8	64.6	72.5	81.7	87.5	2.1
Total	1458.3	1502.6	1633.3	1850.3	2119.8	2.1

* Oil refers here “other petroleum” than light and heavy petroleum used in industry sector only based on energy balance sheets.

The expected average annual growth in electricity demand by the household sector is 11.38 % during the 2012 – 2030 under this scenario. Particularly, demand by urban households is expected to grow from 1170 GWh in 2012 to 5839 GWh in 2030 with an average annual growth rate of 9.3%, while demand by rural households would increase dramatically from 418 GWh in 2012 to 5218 GWh in 2030, with an annual growth rate of 15.1%. This growth rate is very high due to the huge number of rural households that would gain access to electricity by 2030 under this scenario. (Mondal et al. 2018)

Results from ‘Alternative’ scenarios

Under the improved cookstove scenario, it was found out that 241 PJ (13.4 % savings) of energy will be saved in 2030 as compared to the reference scenario. The difference is made by a major decrease in the demand for wood amounting to 233.2 PJ together with small savings in the biomass demand of 7.7 PJ. A comparison with the reference scenario is presented below (see fig. 27). Given the fact that, the biomass sector will still be very much dominant in 2030, these savings will be very beneficial in terms of checking on the levels of greenhouse gas (GHG) emissions and such conditions will boost Ethiopia’s goal of becoming a climate resilient green economy.

Under efficient lighting scenario, the demand for electricity witnesses a slower growth as compared to the growth rate in the reference scenario and large energy savings are expected to be achieved. In the reference scenario, the growth rate of energy demand during 2012 -2030 was 7.6 % per year. However, under this alternative scenario, the figure comes down to 3.4 % annually. The household energy savings accounts to 289 GWh in 2020 and 3061 GWh in 2030 respectively. Therefore, the penetration of efficient lighting units definitely reduces the electricity demand by a large margin. The comparisons of avg. electricity demand (GWh) and percentage of houses electrified using efficient lighting between the reference and the efficient lighting scenarios is presented below (see fig. 28, table 11).

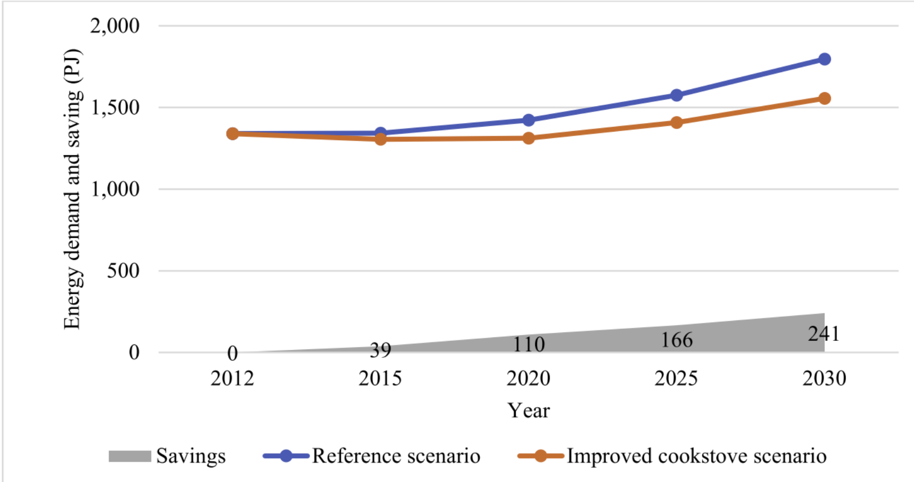

Figure 27: Comparison of energy demand (PJ) between the reference and improved cookstoves scenarios, Source: (Mondal et al. 2018)

Table 11: Comparison of electrified household with efficient lighting share (%) between the reference and the efficient lighting scenarios, Source: (Mondal et al. 2018)

Types/Scenarios	Base Year	Reference scenario		Efficient lighting scenario	
	2012	2020	2030	2020	2030
Incandescent bulb	75	65	50	50	0
Efficient tube lamp	15	20	30	30	60
CFL	10	15	20	20	40

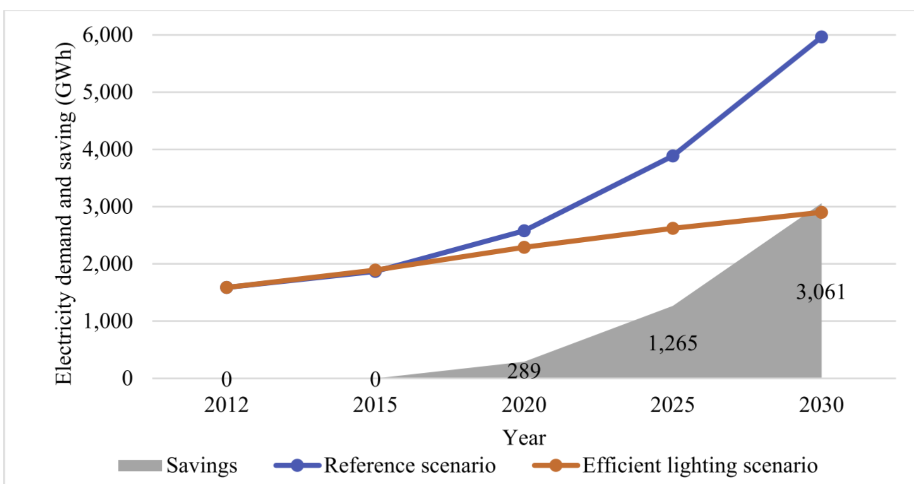

Figure 28: Comparison of avg. electricity demand (GWh) between the reference and efficient lighting scenarios, Source: (Mondal et al. 2018)

Under universal electrification scenario, the sector-wise electricity demand was projected with the LEAP analysis. (Mondal et al. 2018). Following table presents the values respectively (see table 12, fig. 30). With the rapid electrification rate, the electricity access will increase in the household sector as the total electricity demand increases from 4,192 GWh in 2012 to 27,321 GWh in 2030 according to the projections (see fig. 29). The difference with the reference scenario is 5094 GWh under universal electrification.

Apart from that, this scenario projects the electricity demand in the household sector will see an average growth rate of 11.38 % during 2012 -2030. A huge portion of the population living in the rural areas are assumed to get electricity access by 2030, therefore, the projections produced accounts to a dramatic increment of electricity demand from 418 GWh in 2012 to 5218 GWh in 2030 at a rate of 15.1 % annually. Whereas, only 9.3 % growth rate is shown by the urban household. The GHG emissions are supposed to be negligible as the electricity is mostly going to be produced by renewable energy sources. These results indicate the need for large investments in the electricity sector for the targets to be achieved.

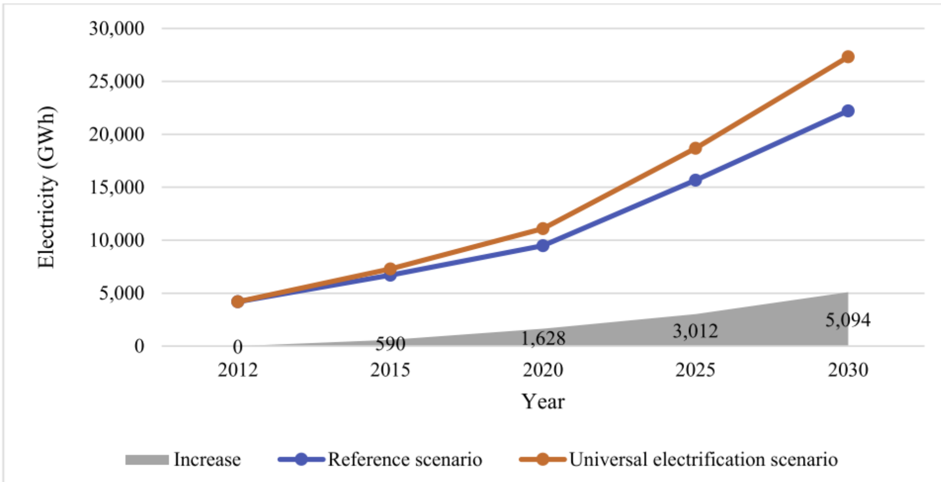

Figure 29: Electricity demand under the universal electrification scenario compared to the reference scenario (GWh), Source: (Mondal et al. 2018)

Table 12: Sector-wise electricity demand (GWh) under the universal electrification scenario, Source: (Mondal et al. 2018)

Electricity	2012	2015	2020	2025	2030
Urban (Residential)	1170	1503	2347	3682	5839
Rural (Residential)	418	895	1860	3215	5218
Agriculture	38	53	77	133	180
Service	1029	1355	1648	2580	3017
Industry	1536	3089	4580	8263	11,998
Transport	0	405	596	817	1069
Total (GWh)	4191	7300	11,108	18,690	27,321

Finally, an overall electricity demand share percentage by different sectors in Ethiopia is illustrated in the figure below under the alternative scenario (see fig. 30). The industrial sector will have the largest electricity demand at a rate of 43.9 % followed by the residential sector combinedly with urban and rural sub-sectors with a growth rate of 40.5 % by 2030. Similarly, the other sectors like transport, agriculture, and other services will have smaller shares of electricity demand increment.

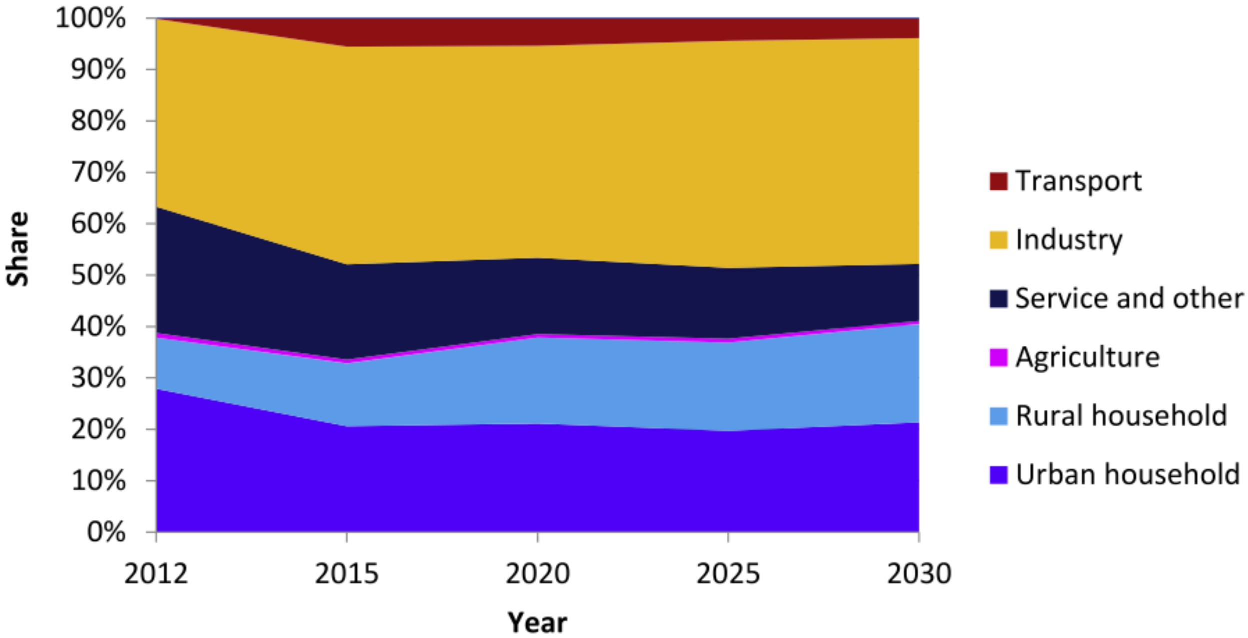

Figure 30: Percentage share of electricity demand by sector under the universal electrification scenario, Source: (Mondal et al. 2018)

3.2.4. Ethiopian Energy Mix

Low access to modern energy and huge dependence on traditional biomass sources has kept the Ethiopian energy system under a lot of pressure. While the country projects a dramatic growth rate of nearly 11 % of GDP in recent years since more than a decade. Maintaining the growth rate in the future requires breathtaking amplification of energy supply. (Mondal et al. 2017) This chapter will define Ethiopia's enormous renewable energy potential and touch on each resource and their energy production in details. The estimated potential data collected for hydropower is 45 GW, wind is 100 GW, geothermal is over 10 GW, and solar with 4 to 6 kWh/m^2. (Mengistu et al. 2015; Ethiopian Electric Power 2016) In table 6 of the previous chapter, the available resource and their exploitation shares have been illustrated. (Ethiopian Electric Power 2016) To have an idea before diving deep, the following graph gives an imagination of the country's energy spectrum in terms of total final energy consumption(see fig. 31). (IEA 2018a)

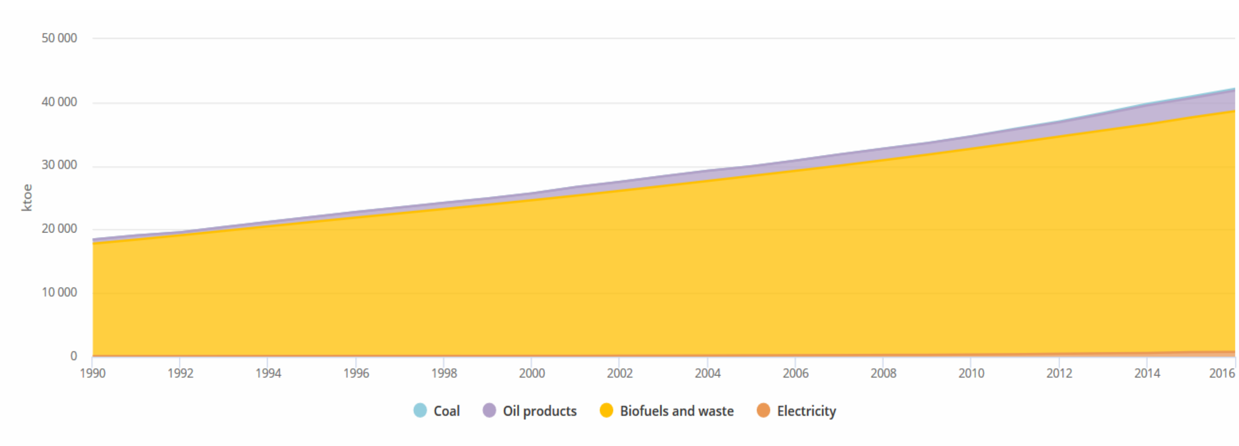

Figure 31: Total final consumption by source, Source: (IEA 2018a)

3.2.4.1. Hydro

Hydropower is the most preferred and utilized source for electricity generation in Ethiopia. According to the government, the levelized cost of electricity generated with hydropower is also the lowest in the country. (Ministry of Water and Energy, Ethiopia 2013b). The presence of large continuous mountain ranges and abundant inland water resources (more than 30 rivers and some large reservoirs) as explained in the section 'Geographical contour' let Ethiopia to be often mentioned as the 'water tower' of Africa. (ANDRITZ 2017) Ethiopia has the second largest hydropower potential in the continent of Africa however, nearly 10% of it has been tapped so far. Nevertheless, it covers more than 90% of the country's electricity demand. As per an estimation, Ethiopia is blessed with about 140,000 Mm^3/year of freshwater and about 86 % of it are surface freshwater resources. (International Hydropower Association 2017)

The largest river basin in Ethiopia is situated in the Blue Nile. To be precise, there are three main river systems within the Blue Nile namely Abbay, Baro-Akobo and Tekeze with the share of freshwater being 44%, 20%, and 6% respectively. Collectively these river systems account to about 117,000 Mm^3 of water discharge annually. (USAID 2018b) The presence of such large water bodies flowing in the deep valleys offers lucrative opportunities for hydroelectric power production with an estimated total potential of 45 GW. More than half of this potential is situated in the Abbay and Omo river basins, where the under construction 6,000 MW Grand Ethiopian Renaissance Dam (GERD) and the recently-completed and commissioned 1,870 MW Gibe III project are stationed (see fig. 34). (International Hydropower Association 2017)

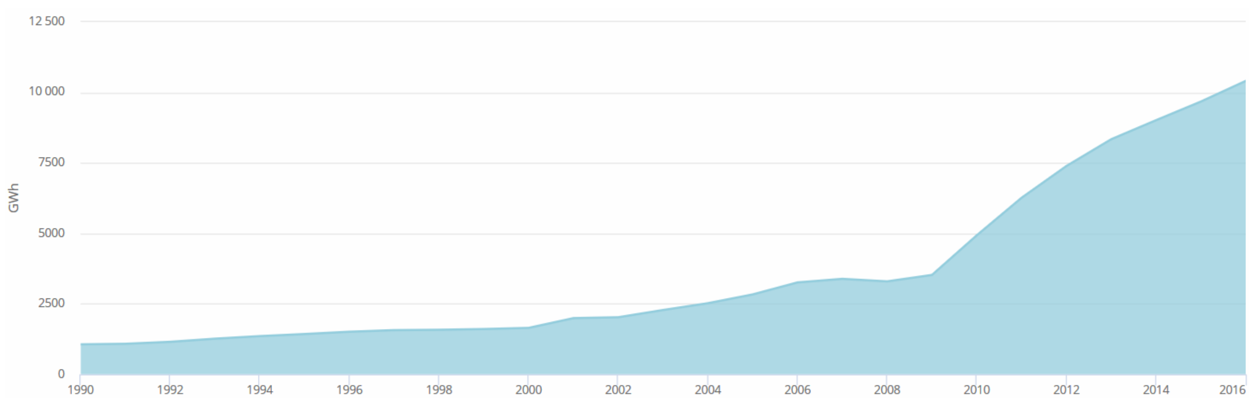

Figure 32: Hydroelectric power generation, Source: (IEA 2018a)

At present, the installed capacity of hydropower is about 4,330 MW with additional 6,600 MW of projects under construction. If everything goes according to the plans, about 14,000 MW could be in operation by the year 2020. (ANDRITZ 2017) The figure above demonstrates the generation profile of hydropower in the country (see fig. 32). The hydropower potential can not only be helpful for electricity generation, but other additional necessities, for example, irrigation, fishery, and other touristic attraction. The river basins of Ethiopia are outlined below in the map (see fig. 33). (Belete et. al 2014) In most of the places of the country, these water basins are used for medium- and large-scale hydropower production and the water flowing out are being used for irrigation in the downstream. As can be seen in the following map that most of the rivers are sourced centrally and flow in all directions of the country. Following is the list of hydroelectric dam projects in Ethiopia (see table 13).

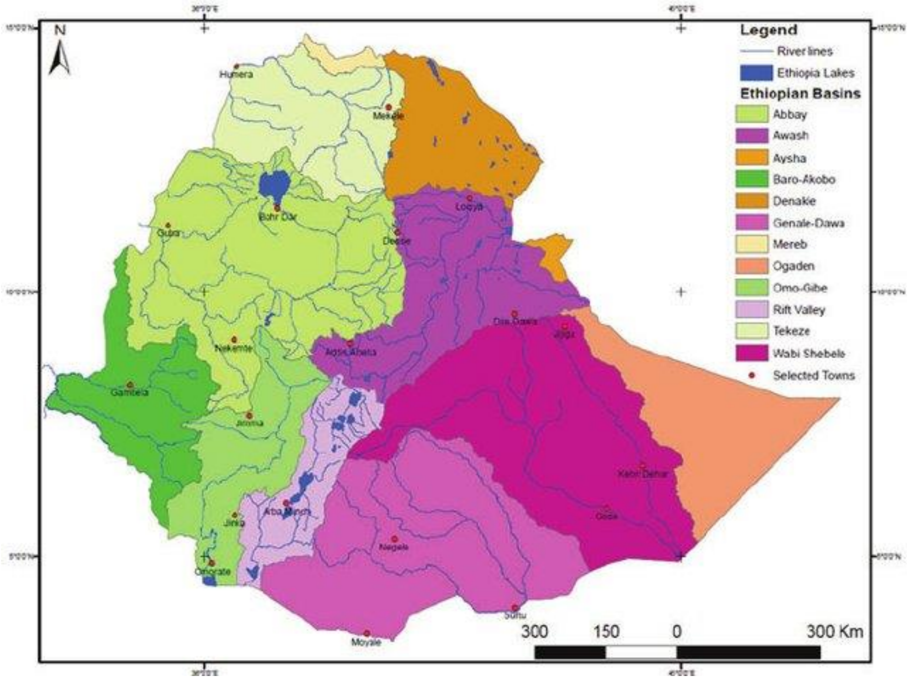

Figure 33: River basin map of Ethiopia, Source: (Belete Berhanu Kidanewold, Yilma Seleshi, Assefa M Melesse 2014)

Table 13: Dams and hydropower in Ethiopia, Source: (Ministry of Water, Irrigation, and Electricity 2017)

Name	Installed Capacity (MW)	Commissioning Year	Basin
Koka HPP	43.2	1960	Awash River
Tis Abbai	11.4	1964	Blue Nile River
Awash II	32	1966	Awash River
Fincha	134	1973	Fincha (Blue Nile)
Gilgel Gibe I	180	2004	Gilgel Gibe River
Tekeze	300	2009	Tekeze (Atbara)
Beles	460	2010	Lake Tana (Blue Nile)
Gilgel Gibe II	420	2010	Omo River
Gilgel Gibe III	1870	2013	Omo River
Fincha Amerti Nesse	100	2012	Fincha (Blue Nile)
Halele Worabese	440	2014	Omo River
Gilgel Gibe IV	2000	2014	Tributary of Omo River
Chemoga Yeda	278	2013	Tributary of Blue Nile
Genale Dawa III	256	2009	Between Oromo and Somali State
Grand Ethiopian Renaissance Dam	6000	2018	Blue Nile River

Figure 34: 6000 MW GERD project (left) and Gilgel Gibe III HPP (right), Source: (Tsegay Hagos), (EJOLT 2018)

3.2.4.2. Small-Scale Hydropower Plants

As learned in the previous section, the topography of Ethiopia is blessed with water resources. Therefore, there are good opportunities for micro-hydro power utilization in the country to increase the electricity access with many mountainous regions with thousands of small streams flowing from the rivers. The micro hydropower (MHP) projects fall within the range of 11 - 500 kW with the minimum catchment area required for their development is thus 1000 km². According to a previous study by the World Bank, Ethiopia possesses a theoretical MHP potential of about 100 MW (The World Bank 2005).

As far as the map presented below is concerned, the most favourable area for MHP installations can be found in the western areas of the country (see fig. 35). Small-scale hydropower potential has not been well utilized so far in the country. During 1950 - 1970, the government started 1.5 MW of MHP projects, however, most of them are not operational anymore due to reasons like the breakdown and voluntary shutdown after the particular areas got connected to the grid. Nonetheless, it would be technically feasible to rehabilitate some of the working MHPs at least for irrigation purposes. (Energypedia 2017) However, a suitable government policy supporting the development of more MHP schemes would help in the process of economic development of the country.

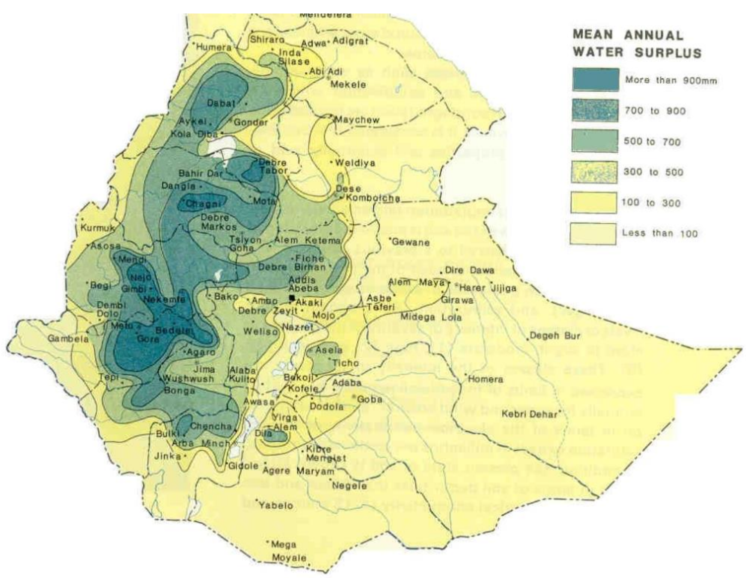

Figure 35: Mean Annual Water Surplus in Ethiopia, Source: (Remmer 2009)

An agency like GIZ EnDev is helping the government in upscaling the MHP mini-grid programs in Ethiopia. GIZ has claimed that a preliminary assessment of more than 400 potential hydropower is underway and will be followed by the feasibility studies (GIZ 2018). GIZ is also planning to restore the Yaye plant and to feed the electricity produced into the national grid.

Other than that, GIZ has implemented four pilot projects namely Gobecho I with 7 kW, Gobecho II with 30 kW, Ererte with 33 kW, and 55 kW Hagara Sodicha respective in the Sidama Zone or Southern Nations, Nationalities, and Peoples' Region (SNNPR). It has also upgraded a watermill into a 20 kW MHP plant in Jimma Zone/Oromia, and further a 10 kW MHP plant in Kersa. On top of that, several pico-hydro projects are also in the pipeline according to GIZ. (GIZ 2018)

3.2.4.3. Wind

To diversify the energy mix under its aspiration of expansion of the renewable energy sector, the government is focusing on wind energy that could be of great importance to supplement hydropower plants, particularly during dry seasons. Although Ethiopia has tremendous potential for wind energy exploitation, the wind energy sector is still at going through its initial developments.

Currently, the Government of Ethiopia is also paying significant attention to wind energy. An amount of 1000 GW worth wind energy potential is present in Ethiopia which is much more than the hydropower potential according to a preliminary study. (Reve 2018) The annual mean wind in Ethiopia is displayed in the map below by Global wind atlas (see fig. 37).

Along with that, it is quite evident that the wind energy conversion process is cost effective and takes less time for commissioning when compared to large-scale hydropower plants. In its first five year Growth and Transformation Plan (GTP) for the period of 2011 to 2015, Government of Ethiopia committed to building eight wind farms for power generation to support the national grid. (Asress et al. 2013) However, as of 2017, only three of them are operational and rest are either under construction phase or waiting to be commissioned (see fig. 38). In an article written by Kieron Monks for CNN, it is mentioned that Ethiopia targets to become the wind power capital of Africa. (Monks and CNN 2017) The figure below illustrates the wind generation profile of Ethiopia (see fig. 36).

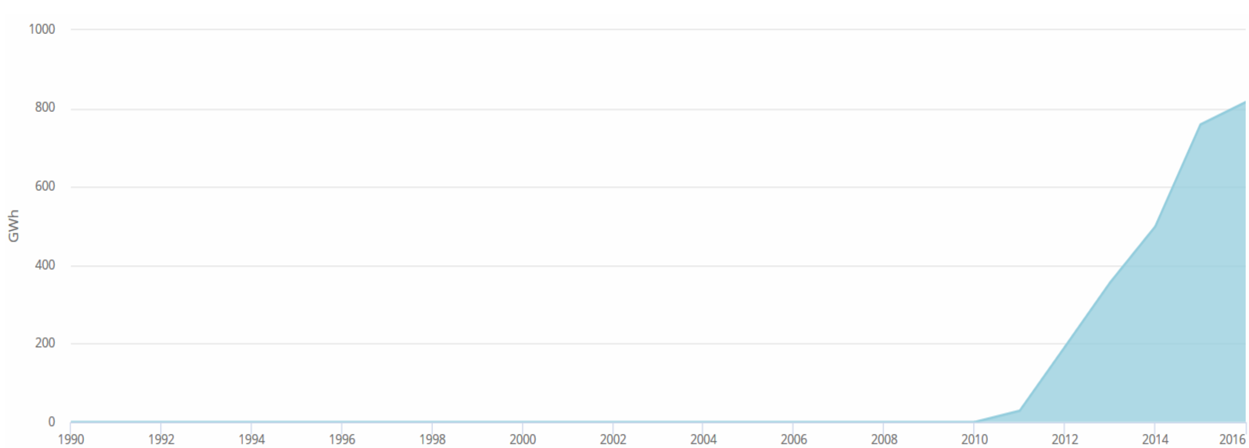

Figure 36: Wind power generation, Source: (IEA 2018a)

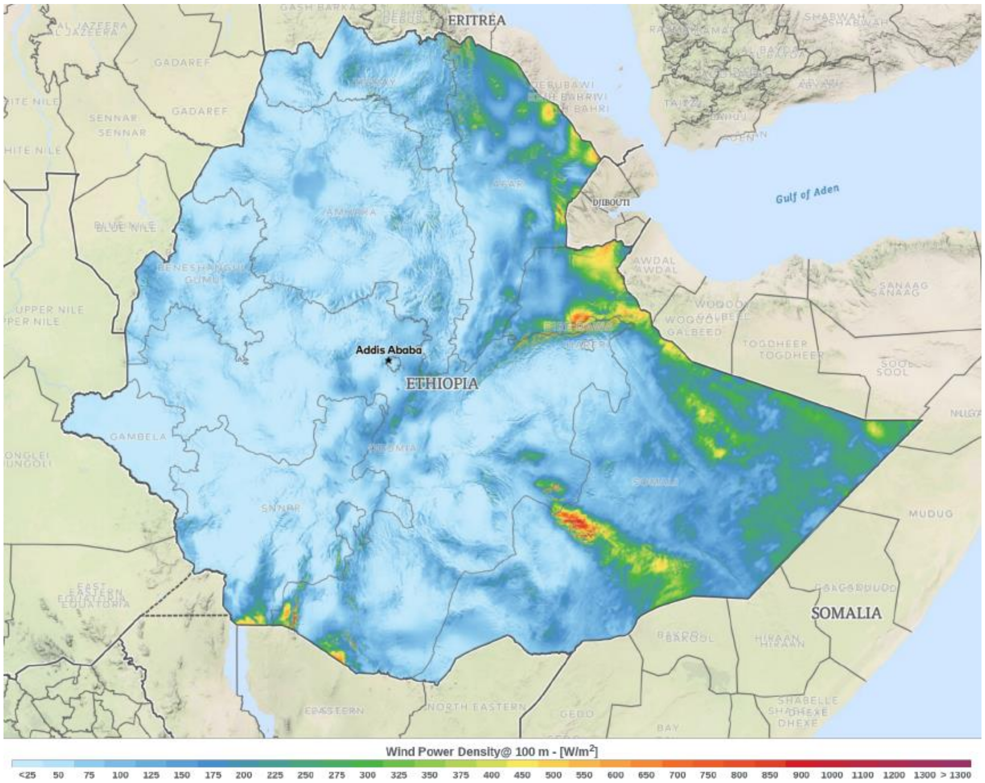

Figure 37: Ethiopia's mean wind density map, Source: (Global Wind Atlas 2018)

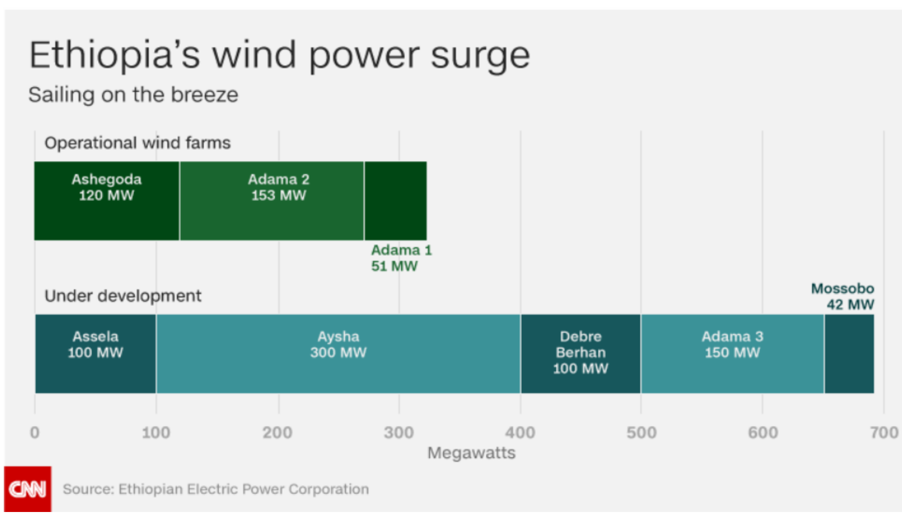

Figure 38: Ethiopia's Wind Energy Share, Source: (Monks and CNN 2017)

The Ethiopian Electric Power Corporation (EEPCo) planned to build 200MW wind farm projects in the country before 2012. The relevant organizations, like GTZ (now GIZ) did the preliminary assessment on 11 sites in cooperation with EEPCo. Ethiopia's first wind power plant project Adama I (see fig. 39) was completed and commissioned with the installed capacity of 51 MW in the Nazareth region of Ethiopia. (EEPCo 2013) Followed by that, two other wind parks were commissioned under Ethiopia's first Growth and Transformation Plan (GTP) namely Ashegoda (see fig. 40) and Adama II (see fig.39) wind power projects with the installed capacity of 120 MW and 153 MW respectively. (Monks and CNN 2017)

Collectively Ethiopia’s total operational wind power share is 324 MW (see table 14) and the government under its second five-year Growth and Transformation Plan (GTP II) is developing three new wind parks namely Aysha project in Somali region, Debreberhan in Amhara region and Iteya in Oromia region. Furthermore, the Mossobo, Assela, and Adama III wind farms are also in the pipeline. (Ivan Shumkov 2016)

Table 14: Ethiopia’s operational wind energy share, Source: (Monks and CNN 2017)

Region	Name	Number of Turbines	Installed Capacity
Nazareth	Adama I	34	51 MW
Nazareth	Adama II	102	153 MW
Mekelle	Ashegoda	84	120 MW

Figure 39: Adama I (left) and Adama II (right) wind farms, Source: (Apache 2012), (ESI Africa 2015)

Figure 40: Ashegoda Wind Farm, Source: (Ross Brooks 2013)

3.2.4.4. Solar

Ethiopia lies at the horn of Africa region which is blessed with yearlong of the sun. The most popular slogan of Ethiopian tourism is “13 Months of Sunshine” and that is because Ethiopian calendar has 13 months in it. (Addis All Around 2018) Even though the country is endowed with so much power from the sun, the solar power sector hasn’t seen many significant developments yet. Introduction of solar-powered projects can allow diversification of Ethiopia’s energy mix and enable it to manage its water resources more effectively. Ethiopia receives solar irradiation of about 5000 – 7000 Wh/m^2 depending on the region and season of the year. (Solargis 2018) A homogenous pattern of around 5.2 kWh/m2/day can be seen in the average solar irradiation of Ethiopia with some seasonal deviations from 4.55-5.55 kWh/m2/day. The western lowlands experience a bit of variation as well according to the map. (Solargis 2018) (Othieno and Awange 2016)

According to some project data compiled by Energypedia, couple of donor-driven solar PV projects have been attempted for rural electrification, but they resulted in failure due to the reasons like the lack of required infrastructure, other factors like awareness, lack of skilled technicians, financing mechanism, market entry, and absence of supportive policies. (Energypedia 2017) The following figure displays the solar irradiation data of Ethiopia (see fig. 41).

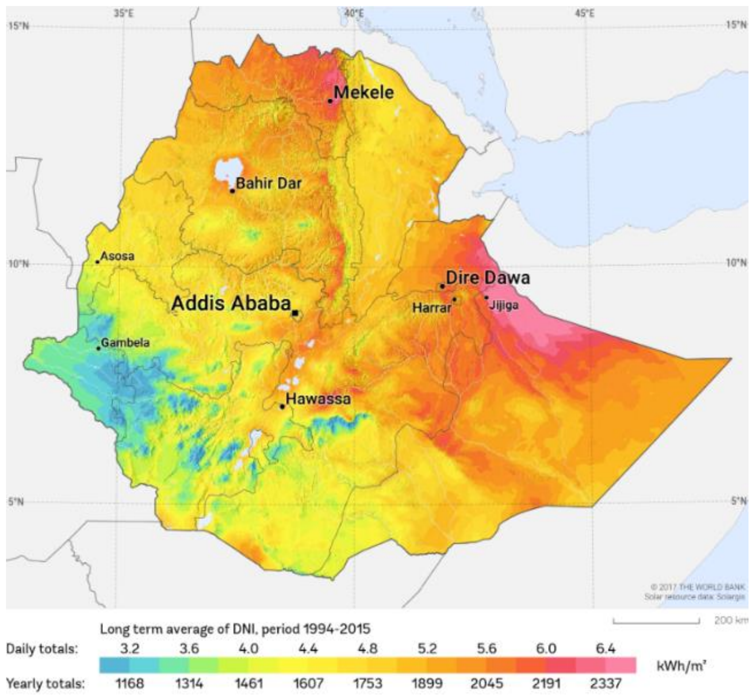

Figure 41: Solar Irradiation in Ethiopia, Source: (Solargis 2018)

Ethio telecom, the Ethiopia telecommunications company insofar has been the major user of PV solar in the country. Standalone power backup is necessary for the telecom installations in the off-grid areas. Therefore, Ethio telecom uses PV solar and diesel generators to power its rural setups which have seen an increment in the last few years with the development of telecommunications in the country. (Expo Group 2018a)

Other applications include radio devices and refrigerators of storing vaccinations for health centers in rural regions of the country. Nowadays, the solar PV projects are primarily promoted by the government under GTPs to suffice off-grid electrical needs. Solar photovoltaics are mainly being promoted to replace fuel-based lighting and off-grid electrical needs. Solar projects in Ethiopia are present in form of solar-powered lanterns, solar home systems (SHS), and other appliances for mainly people in the rural off-grid areas. (Atmosfair 2018) An assembling plant for solar panels has opened in Addis Ababa in early 2013 which is capable of manufacturing 20 MW of solar PV panel per year. (Expo Group 2018a)

EEP plans to construct a 100 MW Solar PV power plant in Metahara located in Oromia region. The project is driven by 'Power Africa' which promotes electricity accessibility in Africa. The construction and ownership of the plant will be given to an independent power producer (IPP) shortlisted through an international tender process. The project site (see fig. 42) for Metahara Solar PV power plant is presented below. (Multiconsult 2017)

Figure 42: Metahara 100 MW solar PV power project site in Ethiopia, Source: (Multiconsult 2017)

3.2.4.5. Geothermal

Geothermal energy is the heat present under the earth's crust. The heat is drawn from underground to run the turbine to produce energy. The unique characteristics of this energy are that it is both regenerative, not intermittent like solar and wind energies, and requires minimum operational energy. As per the geographical location, the country lies over Great Rift Valley and possess the longest section of about 7000 km which makes 13 % of its territory. Studies say that Ethiopia occupies a considerable amount of geothermal reserves, however, still remained untapped. Nevertheless, the government began investigating the inland geothermal potential in the 1970s, however, the geothermal sector still lies at the initial stage. (Kaleyesus Bekele 2018)

"*A new study by the Ethiopian Geological Survey conducted in cooperation with partners, has evaluated the geothermal resources on 23 sites in the country, estimating the overall geothermal potential at 10,000 MW,*" says Alexander Richter from ThinkGeoenergy. (The Ethiopian Herald 2018) In March 2018, the Ethiopian Geological Survey produced the outcomes of 18 months of research and investigation on the potential of geothermal energy in the country. 23 potential sites have been located for current and future geothermal development the (see fig. 44). (World Bank Group 2018; The Ethiopian Herald 2018) In the 1990s, the first geothermal plant of the country with an installed capacity of 7 MW was established at Aluto Langano. It is under rehabilitation process at the movement. Furthermore, the World Bank and the Japan International Cooperation Agency (JICA) have partnered with the Ethiopian government to build a 70 MW geothermal project at Aluto Lango. (see fig. 43).

Figure 43: Aluto Lango Geothermal Power Plant Ethiopia, Source: (CSI Energy Group 2018)

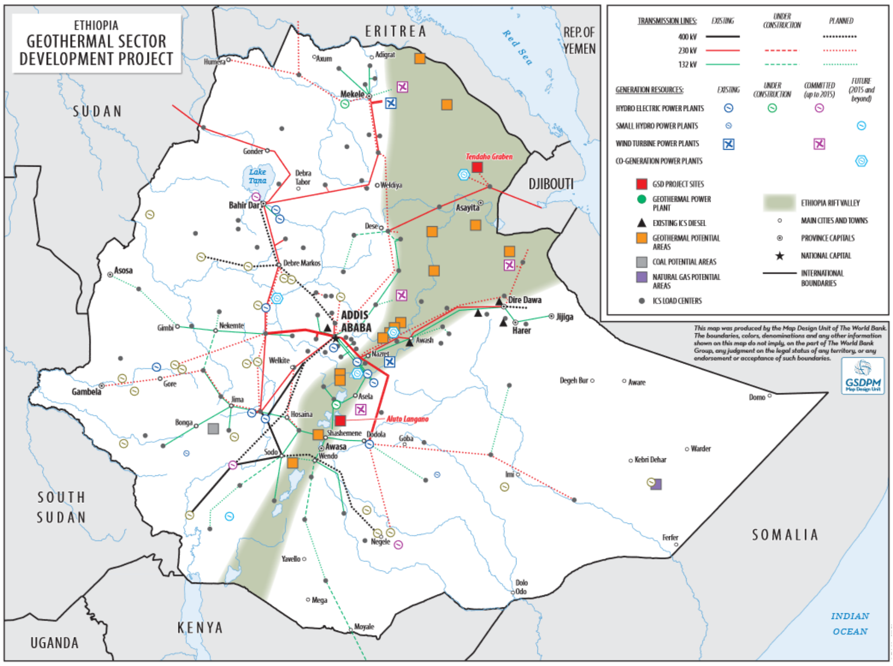

Figure 44: Ethiopia's geothermal sector development project, Source: (World Bank Group 2018)

With the past experiences and results from research and exploration, the government is very optimistic regarding geothermal energy. Therefore, Ethiopian Electric Power (EEP) prepares to increase the installed capacity of geothermal resources by 2,500 MW in 2030 and 5,000 MW in 2037. Recently, the government has signed Power Purchasing Agreements (PPA) with two international energy companies for the construction of two geothermal power plants with an installed capacity of 1,000 MW in Tulu Moye and Cobetti respectively. (Kaleyesus Bekele 2018) Along with that, an American-Icelandic company Reykjavik Geothermal is also interested and investing in the geothermal sector of Ethiopia.

3.2.4.6. Biomass Cogeneration with Bagasse

Cogeneration, also known as combined heat and power technology is the process of simultaneous production of electric and thermal energy from a single energy system and source. (Denny Brett 2018) Cogeneration is popularly accepted in developing nations where sugarcane production levels are high although the cogeneration process can be different fuel based. In the context of Ethiopia, sugar mills employ cogeneration techniques where waste heat is recaptured from the steam coming out of the exhaust of the turbines. This waste heat could have other potential utilization in other tasks of the sugar mills. Some of the cogeneration units which is currently in operation in the country are Fincha, Wonji Shewa, Kesem, Tendaho, Methara. Some upcoming projects can be listed as Omo Kuraz (I and II), Arjo Dedessa, and Kuraz-III. (ExpoGroup 2018b)

Although the above-mentioned sugar factories produce power through the cogeneration units for their internal use in the factories. As of now, there are no current practices power produced from these bagasse-powered cogeneration units being fed to the grid as well as these plants are old and don’t have a convincing power factor. Therefore, the government is planning to rehabilitate and install additional plants to boost up the cogeneration activities. (Karekezi 2007)

3.2.4.7. Biofuels

From the previous chapters, it has been seen that Ethiopia's population is rural and its economy is largely reliant on traditional solid biomass resources. Traditional biomass accounts for almost 95 % in terms of total energy consumption in the country, whereas only 5 % are utilized in form of modern sources of energy. The country imports all its petroleum products (majorly used in the transport sector of the country) from outside which burns almost 80 % of its foreign currency reserve annually. (The Africa Report 2018) On top of that the, they contribute to global warming with their harmful GHG emissions.

Therefore, staying on course with its commitment towards making Ethiopia a climate resilient green economy, reduce poverty by improving employment and save the valuable foreign currency reserve for alternative uses, the government is adamant in the direction of diversification of its energy mix. Locally produced alternatives as bio-fuels and other renewable resources are the key. (Abadi et al. 2017)

According to the Africa Report, Ethiopia launched a biofuel expansion strategy in 2007. To sustain a wide circulation, it also started a large-scale promotion for investment in the biofuel sector. The government has insofar emphasized mostly two types of biodiesel crops namely castor and jatropha. The most commonly used biofuels in the country are ethanol (made from fermented sugars) and biodiesel (made by the oils from specific plant seeds). (The Africa Report 2018)

In the race of privatization, the Ministry of Petroleum & Natural Gas is in the process of formulating the regulation and directives to enable private industries to involve in biofuel sector for the production and distribution, and the sales of biofuel products. The table below shows the list of companies dealing with biofuels in the country at the moment (see table 15). The new directives have been under development under the guidance of 22 stakeholder constituting ministries and personnel from the private sector. The incentives for investment and mechanisms for collaboration between national and international enterprises will help to scale-up in a rapid manner. (Meghan Sapp 2018)

Table 15: List of companies dealing with biofuels in Ethiopia, Source: (Meghan Sapp 2018)

Company Name	Region	Crop Type
Sun Biofuels Eth/NBC	Benshangul	Jatropha
Amabasel Jatropha projec	Benshangul	Jatropha
Jatropha Biofuels Agro-Industry	Benshangul	Jatropha
IDC Investment	Benshangul	Jatropha
ORDA	Amahara	Jatropha
Jemal Ibrahim	Amahara	Castor bean
BDFC Ethiopia Industry	Amahara	Sugarcane/sugar beet
A Belgium company	Amahara	Castor bean
Flora Eco-power Ethiopia	Oromia	Castor bean
Petro Palm corporation Ethiopia	Oromia	Castor/Jatropha
VATIC International Business	Oromia	NA
Global Energy Ethiopia	SNNPR	Castor bean
Omo Sheleko Agro-Industry	SNNPR	Palm
Sun Biofuel Eth/NBC	SNNPR	Jatropha

3.2.4.8. Biogas

In 1979, the technology for biogas was initially introduced in the country. During last 25 years, more than 1000 units of biogas plants were built in different parts of the country, however, about 40 % of those biogas units are not functional anymore due to several reasons such as lack of substrates, mismanagement, lack of knowledge and maintenance, ownership issues and water problems. One of the important reasons of failure could be the integration of standalone systems without proper training and follow-up procedures which can act as a structural demerit for any projects of such scale. The absence of standardized biogas technology also contributed to the failure of the program. (geshete and IEA 2007)

At present, taking notice of the positive environment of biogas development in whole of Africa, the government has geared up for reinventing the biogas sector in the country. During 2008 – 2013, the government had launched the National Biogas Programme of Ethiopia (NBPE) for its initial implementation (Kamp and Bermúdez Forn 2016)

Furthermore, to support scaling up this program, initial subsidies were provided to the users for remunerating the capital costs of installation of biogas units and thus improve affordability. The campaign saw slow but gradual development until a cement crisis in Ethiopia during 2011. The African Biogas Partnership Programme (ABPP) ended its first phase of the NBPE at the end of 2013 with a revision of the target installations 10000 units per year. According to the sources, the first phase concluded the construction of 8063 biogas units. 2480 units in Oromia, 1992 in Tigray, 1892 in Amhara and 1699 in SNNPR of biogas plants were distributed. (Kamp and Bermúdez Forn 2016)

The phase II of the NBPE program ran during 2014 – 2017 with the target installation of additional 20,000 biogas units. The involvement of the private sector was a significant factor in this phase which ensured its steady success unlike phase I. Following graph (see fig. 45) displays a graphical summary of the number of domestic biogas plants constructed in Ethiopia during 1957 - 2018. (Kamp and Bermúdez Forn 2016)

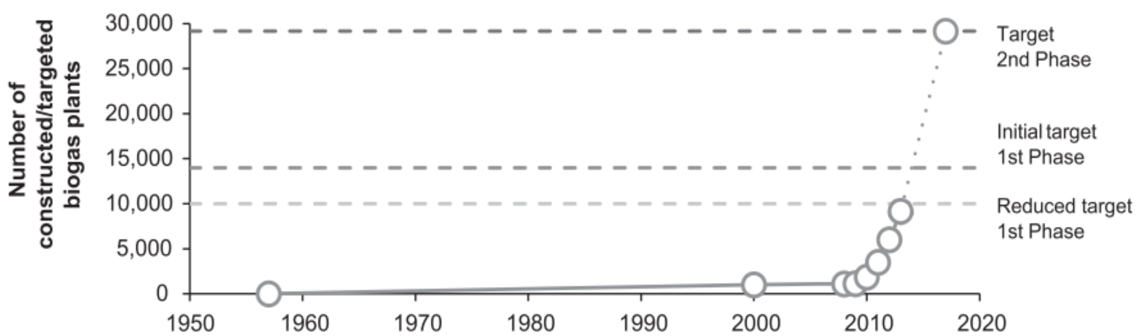

Figure 45: Number of domestic biogas units constructed in Ethiopia, Source: (Kamp and Bermúdez Forn 2016).

3.2.4.9. Waste to Energy

In waste-to-energy incineration plants, trash is subjected to a combustion chamber where they are burned to produce heat for boiling water. The steam from the water drives a turbine to produces electricity. 'waste-to-energy' incineration projects are very unique and have many benefits. It prevents piling on dumping sites, checks landfill and prevents dumping of harmful substances into water bodies, generates electricity, and reduces the methane release into the atmosphere from the landfills. (SWDA 2018)

Recently in August 2018, the Ethiopian government inaugurated and commissioned a USD 120 million 'waste-to-energy' plant (see fig. 46) to the nation, in the outskirts of Addis Ababa with the installed generation capacity of 25 MW. This move was a result of the goals under green economy strategy as well as to tackle the issue of Addis Ababa's piling waste problem which let to increase in the level of pollution levels lately. It is continent's first of its kind 'waste-to-energy' plant and is now operational feeding the electricity to the national grid. The capacity is to harvest energy from 1.4 million kilograms of waste on a daily basis.

"*The Reppie project is just one component of Ethiopia's broader strategy to address pollution and embrace renewable energy across all sectors of the economy and we hope that Reppie will serve as a model for other countries in the region and around the world*," said Zerubabel Getachew, Ethiopia's deputy permanent representative to the U.N. in Nairobi. (Shaban 2018) The power produced by this plant is expected to cover around 30 % of the households in the city of Addis Ababa according to Cambridge Industries (the company responsible for the project). (Shaban 2018)

Figure 46: Reppie Waste to Energy Project, Source: (ESI Africa 2018)

3.2.4.10. Fossil Fuels and Self-Contained Systems

Ethiopia, since decades, has relied on hydropower and wind resources to meet its total electricity demand. Nevertheless, exploration studies are being conducted by the governments since the 1960s directing to the existence of fossil reserves in the country that could potentially be exploited at a business level. It is expected that Ethiopia contains some several hundred million tons share of coal and oil shale under its ground. Apart from that, over 70 billion cubic meters of natural gas is also assumed to be available from the studies over time. More investigations and exploration studies are currently going on by some international petroleum companies in some parts of the country. (Abdella 2013)

On the other hand, at present, 6.1 % of the total generation capacity of electricity in the country accounts to fossil fuel sources. However, often this share refers to the combined installed capacities of both inter-connected systems (ICS) which are grid-connected and additional self-contained systems (SCS) which are not connected to the national grid. (Knoema 2018) On the other hand, Ethiopia's fossil fuel energy consumption is also witnessing an exponential trend (see fig. 47). There are three grid-connected diesel power stations in the country with an installed capacity of 80 MW collectively. They are Kality with 10 MW, Awash 7 kilo with 30 MW, and Dire Dawa with 40 MW. (JICA 2008)

Apart from that, around the country, there are also some privately owned small to very small-scale electrification efforts with diesel engines. The connections are not grid-connected and are scattered around the country to suffice the needs of immediate locals and can be mobile depending on the places of need. The lifetime of such systems usually lasts for a couple of years and therefore, it was hard to collect their data and in view of their incompetence with grid-connected systems in terms of the total cost of electricity, such existing independent systems are neglected in the total electricity share of the country for this study.

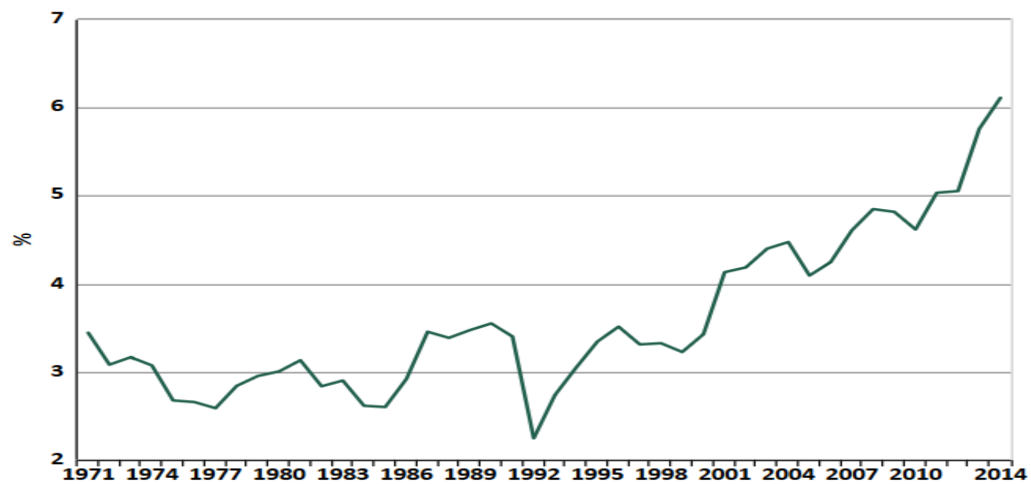

Figure 47: Ethiopia's Fossil fuel energy consumption (% of total), Source: (Knoema 2018)

3.2.5. Energy Policies

In the introduction chapter, Ethiopia is introduced as the area of study for this thesis and after that in the subsequent chapters, the author has presented the country profile, the energy sector demand and the energy sources responsible for energy generation. This chapter will illustrate the policies made by the country in order to come up with solutions in different sectors of energy, their support, and development.

3.2.5.1. Institutions

Ethiopia is a federal republic and the energy sector is under the Ministry of Water, Irrigation, and Energy (MoWIE) and the institutions which are dealing with the work profile of the ministry are portrayed in the figure below (see fig. 48). The state-owned utility company Ethiopian Electric Power Corporation (EEPCo) was established in the year 1997 erstwhile called as Ethiopian Electric Light and Power Authority (EELPA) founded in 1956. EEPCo was responsible for power generation, transmission, distribution, and sales throughout the country. (REEEP 2014)

In 2013, EEPCo split up into two companies namely Ethiopian Electric Utility (EEU) and Ethiopian Electric Power (EEP). EEP deals with the generation, transmission construction, operation, Universal Electric Access Program, and power export. While EEU takes care of the distribution of electricity and sales, EEA acts as the regulatory body for the electricity and energy efficiency board. (Ministry of Water and Energy, Ethiopia 2013a). Institutionally, the proceedings have switched from a monopoly to a more open structure allowing more private sector participation in the energy business of the country. (REEEP 2014)

Note: More information on the history of Ethiopia as well as the beginning of policymaking process in the country are provided in the bonus chapter (see chapter C1, annex) in the annex.

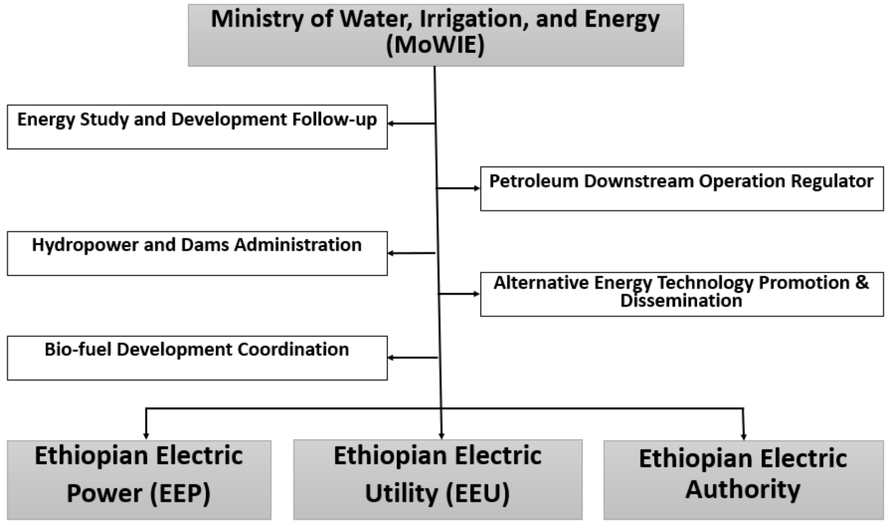

Figure 48: Ethiopian Energy Sector Institutions, Source: (EEPCo 2014)

3.2.5.2. Direct and Cross-Cutting Issues of Energy Sector

As it is evident from the previous chapters that energy production and supply are not coinciding with the total energy demand of the country, hence this gap is putting a lot of pressure on the government to come up with matching solutions to boost the energy sector and thereby, providing benefit to all other sectors which are associated with it. The transition pathway of becoming an industrial economy from an agrarian economy is long but not impossible. With the suitable policies and their proper execution in place, this transition is possible to achieve.

The transition in the Ethiopian energy system towards the expansion of renewable energy sector requires massive investments in the energy sector, therefore, the policymakers have the most important role in ensuring this transition's possible by providing the convenient environment and create favourable conditions for investment in the energy sector of the country.

Energy efficiency can be considered as one of the biggest drawbacks. The electrical losses during transmission and distribution are around 20% in Ethiopia (World Bank and Trading Economics 2015), which is critically higher as compared to the international average electrical losses of 12-13% and slightly higher than the African average of 18 %. (T&D World 2015) Energy efficiency is hardly utilized in all sectors due to the factors like lack of technical know-how, the degree of development and cheap subsidized electricity prices in the country. As seen in the alternative scenarios of the 'energy demand scenarios' chapter, a lot of energy could be saved potentially when energy efficiency will be employed. Along with that, energy efficiency would also help to bridge the huge gap between energy demand and supply. (Mondal et al. 2018)

It was found that these losses are mostly occurring during the distribution of electricity from the national grid to the end users. Currently, the World Bank is financing projects to promote efficiency and modern services like automation of distribution. (Reegle 2014; World Bank 2018b) Efficient power consumptions and sustainable power production are the two most important indicators of climate-friendly energy supply in a broad energy spectrum.

As established in the previous chapters, the traditional biomass is the most reliable energy resource of the rural communities in the country, however, over-consumption and improper management have led to serious issues like the decline in the levels of forestry resources, loss of biodiversity, soil erosion and so on. All these issues collectively are contributing to climate change in the long run. This is going to continue if we follow the energy demand scenarios presented in the previous chapter as biomass is still going to be the most preferred fuel in the future especially wood. (Mondal et al. 2018)

On the other hand, cost of petroleum products import wreaks havoc on the Ethiopian economy as stated in the previous chapters that it almost costs 80% of the country's foreign currency reserve and hence hampering its international trade possibilities. (The Africa Report 2018)

Yet another matter of concern in the energy sector is domestic cooking practices mostly in rural Ethiopia. They are not only inefficient but also heavy of smoke due to incomplete combustion in the poorly ventilated cooking places in the rural households. Hence causing Indoor Air Pollution (IAP), which is a serious health problem among women and children in Ethiopia. (Worku Tefera et Al. 2016)

In Ethiopia, women are also the crucial suppliers of traditional fuels, for example, they go to the forests to collecting wood and BLTs (branches, leaves, and twigs) for their household cooking and heating needs equally in both urban and rural areas where people are dependent on traditional fuel. Therefore, the gender aspects are also important to take into considerations. (Energypedia 2017; Worku Tefera et Al. 2016)

3.2.5.3. Rationale and Objectives of Energy Policies

According to the Government of Ethiopia, some objectives and rationale for the country's energy policies have been derived. They are as follows. (Itoh 2010; Ministry of Water and Energy, Ethiopia 2013a)

- *To develop and utilize the country's energy resources on the basis of overall development strategy ensuring reliable energy supply with energy security and save foreign currency reserve*
- *To clearly define and enforce energy policies favouring equally to energy and other sectors*
- *To employ energy efficiency measures for efficient utilization and decrease energy waste*
- *To encourage measures like privatization and public-private partnerships in the energy sector as well as facilitate skill development on appropriate use and studies of modern energy technologies*
- *To remove bottlenecks and barriers in energy system utilization and to strengthen the implementation of rural energy initiatives*
- *To obtain diversification by integrating new renewable energy technologies in the energy mix by paying close attention to ecological and environmental issues during the development of energy projects*
- *To promote human resources and establish new competent energy institutions for skill development*

3.2.5.4. Country's Energy Policies

The government of Ethiopia has put forward its ambitious goals of huge expansion of the infrastructure in the energy sector. Although Ethiopia's electrification levels remained exceptionally low over the time as compared to other developing countries, new regulations and policies are taking place nowadays to bolster the new developments in the country. Ethiopia is moving fast to become a new industrial economy with the aspiration to achieve middle-income status by 2025. (Reegle 2014; USAID 2018b)

Therefore, the Government of Ethiopia came up with a 15-year turnaround strategy called Growth and Transformation Plan (GTP) which was already roughly touched upon in the previous chapters. This plan outlines three 5-year plans namely GTP I (2010 – 2015), GTP II (2015 – 2020), and GTP III (2020 – 2025) by selectively combining the concepts of a developmental state and a market economy. Ethiopia seeks to transform the country from an agricultural based economy into a manufacturing hub through the Agricultural Development Led Industrialization (ADLI) initiative. Along with that, Ethiopia has also adopted the Climate Resilient Green Economy (CRGE) strategy, which calls for harvesting energy from renewable sources. The government is also positive towards integrating energy-efficient technologies in the electricity, transport, and industrial sectors. (International Hydropower Association 2017)

The government has taken a number of policy measures in the last two decades in the energy sector. In 1994, 'National Energy Policy' was launched for the first time to focus on the country's household energy issue. The policy promoted the schemes such as *agro-forestry, use of modern fuels from renewable sources, and energy efficiency measures in biomass fuels*. However, this policy didn't achieve a lot due to the recurrent issues with management and implementation. (Reegle 2014). Following table lists out the significant energy policies in the country (see table 16).

Note: This study will mostly focus on the policies developed after the millennium because of the better availability of data

Table 16: Energy sector policies in Ethiopia, Source: (IEA and IRENA 2018; USAID 2018b; Ministry of Water, Irrigation, and Electricity 2017)

Policy Name	Year	Policy Type	Policy Target
Ethiopian Rural Energy Development and Promotion Centre (EREDPC)	2002	Regulatory Instruments, Economic Instruments>Market-based instruments	Solar
The Rural Electrification Fund	2003	Policy Support>Strategic planning	Multiple RE Sources>All, Multiple RE Sources>Power, Bioenergy, Geothermal, Solar, Hydropower, Wind
Universal Electricity Access Programme	2005	Policy Support>R&D, Strategic planning	National Electrification
National Biogas Programme (NBP)	2007	Policy Support>Strategic planning	Multiple RE Sources>All, Hydropower
Growth and Transformation Plan (GTP) 2011-2015*	2011	Policy Support>Strategic planning, Economic Instruments>Fiscal/financial incentives>Loans, Economic Instruments>Fiscal/financial incentives>Grants and subsidies	Hydropower, Multiple RE Sources, Geothermal, Bioenergy
Climate Resilience and Green Economy Strategy (CRGE)	2011	Policy Support>Strategic planning	Hydropower, Multiple RE Sources
Scaling-Up Renewable Energy Program for Ethiopia (SREP)	2012	Policy Support>Strategic planning	Multiple RE Sources>Power
National Energy Policy 2013	2013	Regulatory Instruments>Auditing	Bioenergy

Growth and Transformation Plan II (GTP II) 2016-2020	2016	Policy Support>Institutional creation, Economic instruments>Fiscal/financial incentives>Loans, Economic Instruments>Fiscal/financial incentives>Grants and subsidies	Multiple RE Sources>Power
Ethiopia Solar Auctions	2017	Research, Development and Deployment (R&D)	Multiple RE Sources
National Electrification Program (NEP)	2017	Technology Deployment, Policy support, Financial advice and incentives	Multiple RE Sources>Power> grid and off-grid solutions

* This policy has already been suspended after the target year 2015

In 2004, under Universal Electricity Access Program (UEAP) the Government-owned utility EEPCo started the national grid expansion to villages and towns with at least 5000 residents. However, there was a contradiction, vicinities with fewer households were often considered for grid connection only if the regional governments agreed to finance the setups. (The World Bank 2018b) There are huge prospects for microfinancing through viable financial schemes under privatization in both rural and urban sector for off-grid technologies. Therefore, the relatively high costs of transmission and distribution to such secluded settlements become non-economical. Either grid extension which incurs high investment costs or off-grid electrification drives (with future plans for grid connection) can be a key to success.

Ethiopia also participates in the Scaling-Up Renewable Energy Program (SREP). This is an Investment plan, which comes under the GTPs with the objective to scale up the electricity production capacity up to 10 GW in 2015 to 22 GW in 2030. This program also entails additional investments to expand the transmission and distribution system. (Climate Action Tracker 2017)

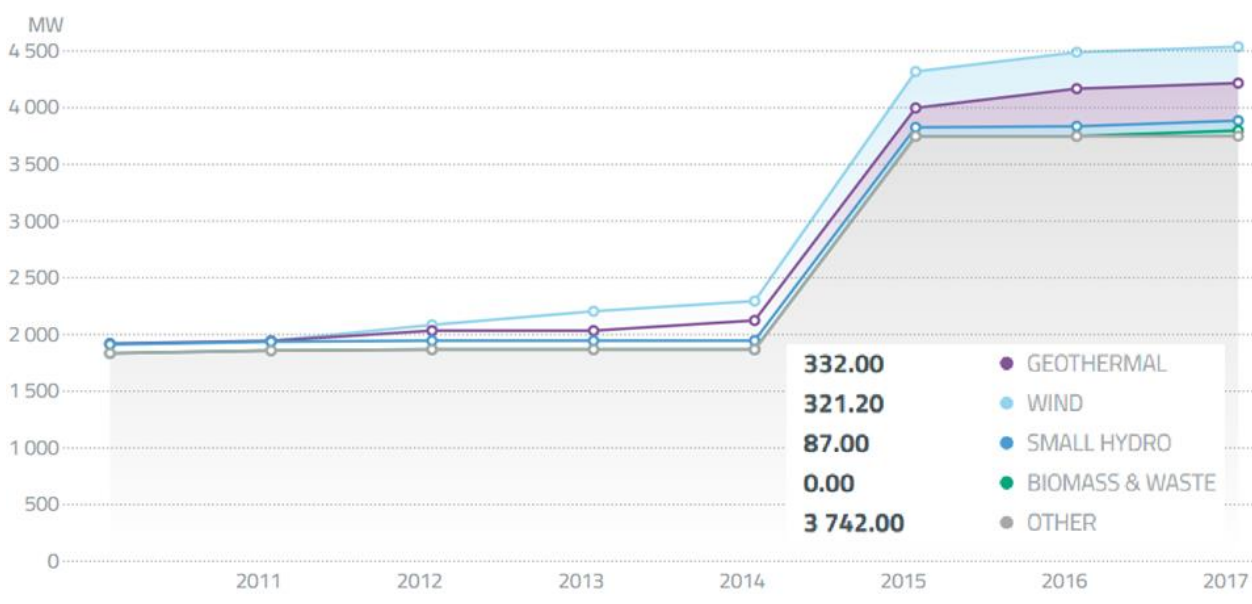

Figure 49: Total installed capacity of Ethiopia, Source: (Climatescope 2018)

During 2010-2015 under GTP I, the expected increase in the installed capacity was 10 GW from 2 GW potentially through hydroelectric projects. The country currently operates with a total generation capacity of 4.3 GW (see fig. 49) with more projects like GERD being under construction which will boost the generation capacity with an additional 6 GW. Conservation of natural resources by the implementation of environmental laws was one of the key highlights of GTP I. According to (Mondal et al. 2018), a growth rate of 11 % or more was expected during GTP I, however, the real numbers averaged to 10.3 % during that period of time (see fig. 16). (The World Bank 2018a)

Under GTP II, Ethiopia has planned to increase the installed capacity to over 17,000 MW by the year 2020. On the other hand, Ethiopia wishes to sustain its economic growth in the next 5-year plan of GTP III which is expected to start in 2020 with an objective of becoming a renewable energy hub in the region of East Africa. (USAID 2018b). GTP II provided electrification targets explicitly during the policy period, such as 6.955 million grid-connections, distribution of 3.6 million solar lanterns and 0.4 million solar home systems (SHS) with an overall target of electrifying 54 % of household by 2019-20.

In November 2017, the government launched its new National Electrification Program (NEP) with the assistance of the World Bank. The objectives are supporting the total electrification to achieve universal electricity access by 2025 (see fig. 55) Both grid connections and off-grid technologies are encouraged to cover 100 % electricity share of the country with off-grid taking 35 % and grid-connections taking 65 % of shares for providing electricity to the citizens. Standalone solar systems and mini-grids are going to be scaled up. Other than that, several institutional reforms will be placed to promote gender equality and woman empowerment. To facilitate citizens' involvement in the process, several informational campaigns will be conducted to increase awareness about the use of electricity services. (World Bank 2018a)

Chapter 4: Dimensional Analysis with respect to the analytical framework

4.1. Ethiopian Energy System transition

In chapter 2, the energy transition characteristics were detailed. With the graphics from World Energy Forum, the system imperatives and all the stakeholders involved in the associated sectors in a given energy transition process were identified. Followed by that the analytical frame for this study was introduced as Multilevel Perspective (MLP). MLP is very helpful when it comes to analyse socio-technical energy transition. The term sociotechnical means that the topic under study contains both technical and social elements, which are interlinked. On the other hand, it was one equally important task for this study to understand how energy transition takes place in the form of socio-technical transformation. Furthermore, different dynamics and typology of the transition process have also been introduced and explained in a very detailed manner to better understand the interaction between different levels of MLP. These interactions result in the change of dynamics and bring about changes in the society and hence lead a transition in long-term, in this case in the energy sector of Ethiopia.

This chapter will initially identify the different stakeholders responsible at different socio-technical levels in the context of Ethiopia. Then the author will interpret on how such an energy transition took place/will take place in a developing country like Ethiopia based on the analytical framework along with supporting facts and figures presented in first three chapters of this paper by studying the interactions of different socio-technical levels and technological niches. Followed by that, the author discusses the current affairs in the country which also will contribute to the energy transition path of Ethiopia but are not included in this dissertation.

4.2. Assessment of Energy System transition through Multi-Level Perspective

The enabling factors of the energy transition process control the ‘system imperatives’ mentioned in chapter 2.1, ‘Energy Transition Characteristics’. Since, they make sure the stability of social, political, and economic structures of a country to facilitate the transition to be reliable and inclusive which as a result brings about the secure economic development. Such structures will be easily identified in the interpretation section of this chapter where the dynamics of the transitions will be explained in the Ethiopian context.

As learned in chapter 2, The MLP approach studies how the long-term transformation is influenced by factors at three levels: the exogenous ‘landscape’; the dominant societal function provider or the ‘regime’; and the ‘niche’, the level where the new innovation emerges. Following are the indicators to define all three levels of socio-technical transformation (see table 17).

Table 17: The MLP levels and their indicators, Source: (Kamp and Bermúdez Forn 2016)

Socio-technical Level	Indicators
Landscape	• Political and economic stability • Suitability of economic climate for enterprises and innovation • Extent of poverty • Physical geography and climate suitability • Availability of natural resources • Education levels and literacy rates • Presence of different population groups/tribes/languages/culture • International funding and technology transfer programmes
Regime	• Stability in regime • Suitability of sectoral policy • Amount of lock-in in the regime
Niche	• Completeness of network of actors • Alignment of a network of actors • Match between expectations and actual development • Presence of first-order learning • Presence of second order learning

4.2.1. Socio-technical Landscape in Ethiopian Energy Sector

It is known that the landscape contains the deep structural trends and factors which influence regime and niche levels from the top. A significant array of entities and processes can be considered at this level, including macroeconomic international factors like economic growth, oil prices, wars, terrorism, and climate change, there can also be landscape entities in national level such as population growth, level of corruption, cultural aspects (status, power differences, and presence of different ethnicity) and availability of natural resources and raw materials. (Davidson et al. 2018) Being at the macro-level, the landscape level has the slowest dynamics. Although these trends usually change relatively slowly and are hard to change, they also include unexpected events from within or outside the country which is unpredictable.

In case of Ethiopia, at the landscape level, economic fluctuations, political instability, and poverty constituted the most relevant barriers for energy transition in the past and also in some amount at present as well, in author's point of view. The Federal Democratic Republic of Ethiopia is categorized as one of the poor countries in the world ranking 69 among other countries, although the country has experienced sustained economic growth (see fig. 50) over the last years and the gross national income (GNI) per capita has increased almost 5 to 7 folds over the last 30 years (World Bank 2017). GNI per capita, (current international USD) was USD 704 in 2016. Major development took place mostly after the millennium (see fig. 51). However, still Ethiopian overall population share is more rural than urban, and poverty is a big problem in the country. *Poverty goes beyond per capita income; it affects people's quality of life and their ability to overcome their misery, hence poverty itself becomes a trap*. (Glinavos 2006)

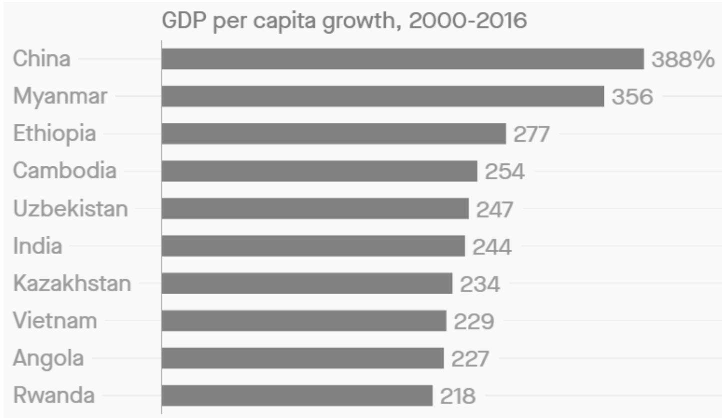

Figure 50: Millennium's fastest growing economies, Source: (Kopf 2017)

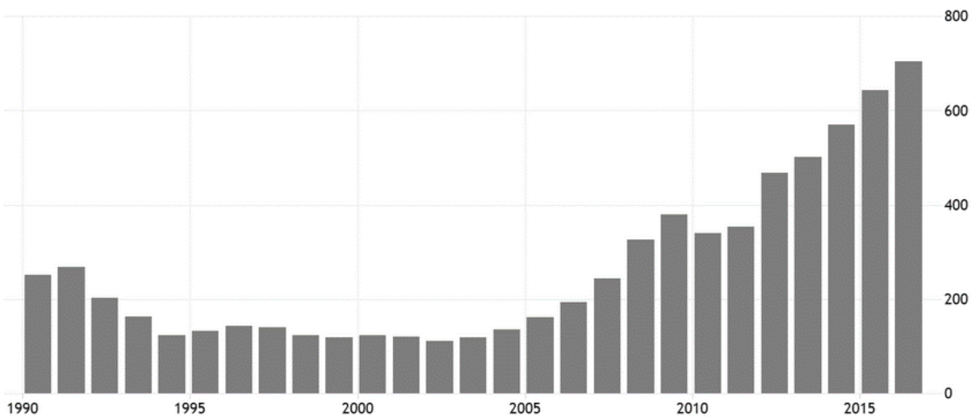

Figure 51: Ethiopia - GNI per capita, Source: (The World Bank 2016b)

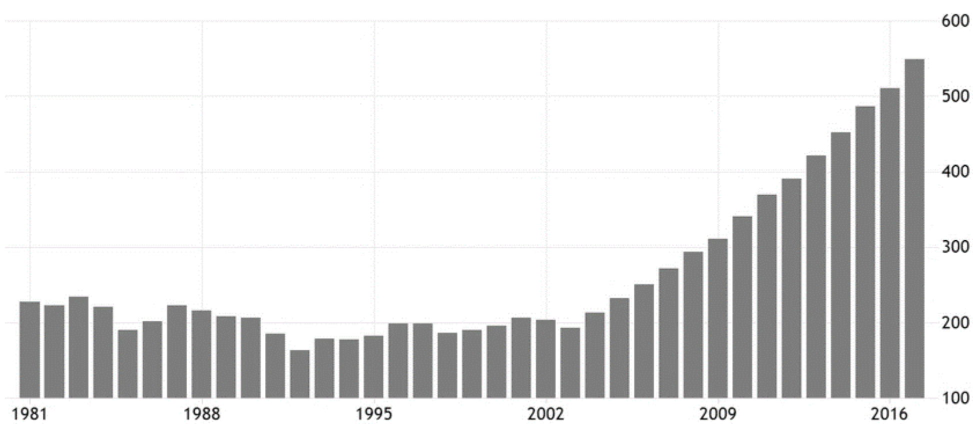

Figure 52: The Gross Domestic Product per capita (GDP) in Ethiopia. Source: (The World Bank 2016e)

In 2017, the Gross Domestic Product (GDP) per capita reached a record high at 549.80 USD in Ethiopia. It is now the equivalent to 4 % of the world's average. From 1981 till 2017, the GDP per capita in Ethiopia grew with an average of 262.69 USD, reaching an all-time high of 549.80 USD in 2017. The record lowest was 163.60 USD in 1992 (see fig. 52). (World Bank 2017)

The political system in the country as mentioned above is a federal republic. The Ethiopian People's Revolutionary Democratic Front (EPRDF), a four-party coalition, has been ruling in Ethiopia since 1991. It is a leftist political coalition of four parties namely Amhara Democratic Party (ADP), Oromo Democratic Party (ODP), Southern Ethiopian People's Democratic Movement (SEPDM) and Tigray People's Liberation Front (TPLF). (GlobalSecurity 2018) This coalition has representatives from different regional and ethnic groups.

Political instability as described as one of the landscape entities constitutes an additional constraint, both internal and external to the country. Before 2018, Ethiopia has been experiencing recurrent mass protests, riots, and ethnic conflicts since 2015, for example, the serious conflict between Oromo and Somali people. and that have taken thousands of lives and displaced a mass portion of residents of the country. Based on a report from the Internal Displacement Monitoring Centre, about 1.4 million residents got displaced only in the first half of 2018 due to this rising unrest. (Sevenzo and CNN 2018)

These political disturbances in the country led to the declaration of a state of emergency first in October 2016 and again in February 2018. Externally, it had affected its currency value which was abruptly decreased by 15% in October 2017 and also brought down the GDP to 10.9 % in the financial year 2017. (Africanews 2017; The World Bank 2018a) Citing the reasons of high risks of investment in the country, western donors and investors alike grew skeptical regarding the ongoing projects. At the moment, Ethiopia is facing the issues of massive youth unemployment, rising public debt, inflation, and foreign currency shortages, and on top of that, an internal border dispute between Oromia and Somali regions. All these crises had resulted in the second declaration of emergency and led to the unexpected resignation of the then Prime Minister of Ethiopia; Mr. Hailemariam Desalegn in February 2018. (Aljazeera 2018)

One more hindrance at the socio-technical landscape level would be the corruption in the country. According to the Corruption Perception Index 2017 by Transparency International, *out of 180 countries, Ethiopia ranks 107 with a score of 35 out of 100 in terms of corruption*. (Transparency International 2017) Apart from that, as mentioned in previous chapters, approximately, 34 % of Ethiopia's over 102 million inhabitants live below the poverty line. (IEA 2016). Ethiopia's national projects were primarily based on public investment and recently the government has been showing interest and paying more attention towards improving the participation and involvement of the private sector. With the help of the major initiative like Agricultural Development Led Industrialisation (ADLI) under Growth and Transformation Plan II (GTP II), it is expected that the private sector will flourish. This raises hopes for tackling the issue of inadequate financing possibilities (another landscape factor) because the changes in the global market such as continuous depletion of foreign currency reserve and falling revenues from export commodities are challenging the ambitious economic development prospects of the country. (Jon Harald Sande Lie and Berouk Mesfin 2018)

Being poor and still maintaining a rapid development in a country like Ethiopia has put the status of the country at a difficult state with growing inequalities between the rural and urban sectors as well as between men and women which on the other hand, increases the gender gap. (Jon Harald Sande Lie and Berouk Mesfin 2018) argues in favour of Ethiopia's strong ownership of the Millennium Development Goals (MDGs) and integrating them into national policies for poverty reduction since 2005.

Except for MDG 3 on the encouragement of gender equality and women empowerment, and MDG 5 for maternal health, Ethiopia has showcased successful implementations in the field of MDGs. At the moment, the Agenda 2030 pertaining to the Sustainable Development Goals (SDG) have also been integrated into the current GTP II targets and objectives. (National Planning Commission 2017)

Shortage of educated and skilled labour is also another factor at the socio-technical landscape level in Ethiopia. Often it is hard to find skilled labour to match up with the increasing rate of development. Although the facts and figures of the government boast the increment in the quantity in the education, however quality of education is still questionable. Ethiopia has certainly made substantial progress in the education sector. The numbers have reached up to 25 million students as of today from 10 million a decade ago in the education.

Ethiopia has insofar managed to maintain and enhance the learning progress at different levels of education. To bolster up this upward trend, Ethiopia has developed a sectoral plan namely the 'Education Sector Development Program V (ESDP V)' for 2015 – 2020 of ensuring quality education, build vocational training institutes and strengthen the higher education institutions. (Global Partnership for Education 2018). On the contrary, the unemployment rate is witnessing a mild decrement (see fig. 53) which, in a long-term, is good news, however, for a country to keep up with the rapid national development and to reach up to global competition, skill development is very essential.

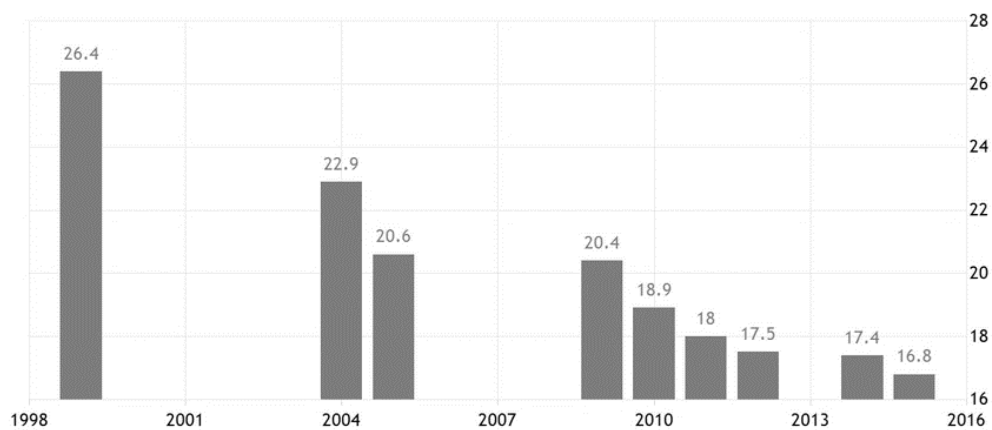

Figure 53: Ethiopia unemployment rate, Source: (The World Bank 2016d)

In the author's point of view, this gap could be filled with the help of international funding and technology transfer from the developed nations along with the immediate efforts from the national government. Global Partnership for Education (GPE), International Monetary Fund (IMF), World Bank, Department for International Development (DFID), United Nations International Children's Emergency Fund (UNICEF), United States Agency for International Development (USAID) are some of the international agencies working at the moment in Ethiopia for the betterment of education sector. (Global Partnership for Education 2018)

Other indicators include the availability of natural resources, which in this study would be the resources related to the energy sector such as energy resources, conversion technologies, other human and technological resources. Throughout the whole paper it has been established that Ethiopia is endowed with enormous potential of natural resources and if tapped well, it has the capacity to be the front-runner in the whole African continent.

In chapter 3, under the section of Energy Demand Scenario, the availability of natural resources has been briefly described and thoroughly explained in further sub-sections of 'Ethiopian Energy Mix'. Not to forget regarding the availability of resources is also the increasing rate of deforestation projected in the section 'Climate and Environment' which is responsible for hampering the availability rate.

Finally, one very important factor which is also an integral part of the Ethiopian socio-technical landscape is the international oil prices fluctuation. Previously, in the 'Biofuels' section, it is established that Ethiopia spends almost 80% of its foreign currency reserve in the oil products imports. (The Africa Report 2018) Development in the internal energy sector with the introduction of new niche technologies at the regime level can significantly alter the scenarios according to the author and save the country's valuable foreign currency for alternative uses. Along with that, there are also factors such as the geographical contour of the country as discussed in the country profile, is very uneven. The fact that settlements are far away from each other acts as a positive drive for new off-grid electrification technologies (niches) to fill the gap and provide the energy services which are not yet available via national grid.

4.2.2. Socio-technical Regime in Ethiopian Energy Sector

After having described the potential socio-technical landscape actors which could be responsible for the interactions at the macro level, this section focuses on the most important socio-technical level i.e. the 'Regime'. In previous chapter, regarding the analytical framework, the regime description was presented as well as its interactions within itself and the different socio-technical levels to define the transition. Furthermore, regarding the country context, the country's resource potential, exploited shares, demand scenarios, energy conversion technologies, and policies were the part and parcel of chapter 3. Therefore, now in this section, the author analyses the existing established systems which are catering to the energy sector of Ethiopia and the actors responsible particularly for the electricity sector and play different roles in the expansion of national electrification plans.

As explained in chapter 2, the socio-technical regime is the level of already-established technologies in a society and in this case, Ethiopia. It lies in between the levels of socio-technical landscape and technological niches. The regime itself is generally stable and like any established environment, there is usually resistance to the installment and commencement of new technologies at this level. This is because existing technologies which are already established are locked-in or path dependent which means they follow well-rooted trends which have been working well for the society.

Ethiopia is a lower-income developing country which is advancing towards becoming a middle-income status country by the year 2025. More access to the electricity along with other resources for the people in the country in a climate-friendly manner is one scope of development. Therefore, a 'leapfrogging' approach towards development can be the convenient option in the author's point of view. However, the identification of different existing regimes in the Ethiopian energy sector is necessary.

Although the whole energy system could be considered as one regime, considering the case of Ethiopia, which is overall fully dependent on traditional biomass for its energy demand. However, the electricity generation is accountable to majorly the hydropower resources. Therefore, traditional biomass and electricity spectrum are considered as two regimes for this study respectively.

4.2.2.1. Traditional Biomass Regime

(Karekezi et al. 2005) states that there must be a relative interdependence between the poverty levels and traditional biomass usage in many developing and lower developing nation setting. Considering unaffordability being the biggest reason, it is true that the poorer the society is, the greater its dependence on traditional biomass resources. Biomass energy is most exploited in the form of fuelwood by the poor rural households in the domestic sector since fuelwood is considered to be the cheapest energy option available, although the cost of labor, effort and other externalities of fuelwood stay un-quantified. (Batidzirai et al. 2006)

A similar trend can also be traced in Ethiopia. With respect to the Sankey diagram of Ethiopia, it is clearly evident that traditional biomass is the main source of energy in the country (see fig. 16, chapter 3). Biofuels and waste account for more than 91 % (see fig. 18) of the primary energy consumption and almost 81.2% of which is provided by woody biomass especially firewood. Apart from that, other fuels crop delivering to the biomass regime are 8.1 % of crop residue and 9.1% of dung cakes respectively. (Yurnaidi and Kim 2018) Other biomass fuel options also include the utilization of bagasse from sugarcane, charcoal, and locally manufactured bio-briquettes. The main uses for biomass fuels are for baking the locally widespread food called injera and other cooking needs. A study survey conducted by Ethiopian Ministry of Water and Energy to develop a 'Biomass Energy Strategy' for Ethiopia which was also supported by European Union Energy Initiative Partnership Dialogue Facility (EUEI PDF) states the following result on total national consumption of biomass fuel per region as 2013. (Geissler 2014)

Table 18: Total national biomass fuel consumption per region, Source: ((Ministry of Finance and Economic Development, MoFED 2013)

Region/Fuel	Round Wood (tons/year)	BLT (tons/year)	Charcoal as wood (tons/year)	Total wood (tons/year)	Total Wood (%)	Residues (tons/year)	Dung (tons/year)	Charcoal (tons/year)
Addis Ababa	684,228	-	1,060,439	1,744,667	2%	-	39,964	212,088
Afar	830,552	-	1,195,154	2,025,706	2%	-	49,364	239,031
Amhara	9,549,847	8,042,277	6,603,169	24,287,123	23%	3,867,504	8,221,892	1,339,000
BSG	419,308	271,709	202,893	893,911	1%	427,246	188,435	40,579
Diredawa	219,831	54,698	359,246	633,774	1%	39,971	29,548	71,849
Gambela	181,653	74,736	96,236	364,659	0%	67,069	44,966	20,735
Harari	136,728	38,463	225,685	400,876	0%	28,108	21,501	45,137
Oromiya	17,812,299	11,070,636	9,921,703	38,804,638	37%	7,571,451	6,261,813	1,984,341
SNNPR	15,264,304	7,185,536	3,564,630	26,014,470	25%	7,539,192	2,229,843	712,926
Somali	2,520,644	211,155	3,203,569	5,935,369	6%	152,929	220,755	614,467
Tigray	614,995	1,284,533	2,167,743	4,067,271	4%	31,256	5,511,309	433,549
Total	48,234,389	28,233,742	28,600,468	105,172,465		19,724,725	22,819,390	5,713,700

The household sector by far is the major consumer of energy in Ethiopia. While the household sector makes up to about 89.8 % of the total national energy consumption, the remaining 10.2 % is shared among agriculture, transport, industry, and service sectors. Traditional biomass constitutes the highest share of total energy consumption in the country.

95% of the total national energy consumption according to (Konemund 2002) is fulfilled by traditional biomass including 98% of the total household energy consumption. While fuelwood combined with charcoal and dung combined with crop residues account to 83% and 16 % respectively, electricity and petroleum together constitute the final 1% out of the total household energy consumption. (Geissler 2014). According to estimates by Woody Biomass Inventory and Strategic Planning Project (WBISPP), national woody biomass stock was 1,149 million tons with an annual yield of 50 million tons in the year 2000. (Energypedia 2017)

4.2.2.2. Electricity Regime

In spite of the fact that Ethiopia is graced with an abundance of renewable energy potential, only a handful portion of the population enjoys access to electricity. The following figure presents the latest data on the percentage of the population with access to electricity (see fig. 54). This proportion is growing in terms installed infrastructure in the country to increase the electricity access, for example, commissioning of new hydroelectric dam projects like Gilgel Gibe III, GERD and many others as mentioned in chapter 3, 'Ethiopian Energy Mix'.

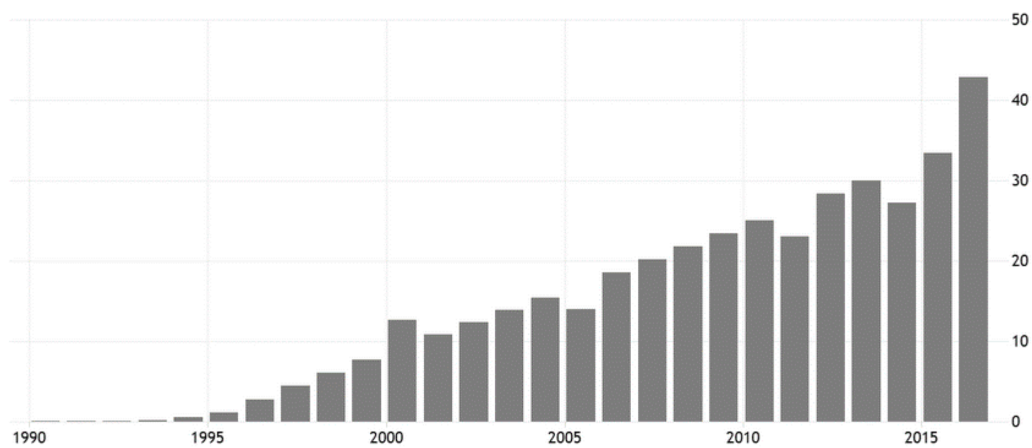

Figure 54: Ethiopia - Access to electricity (% of population), Source: (The World Bank 2016c)

Ethiopia has Interconnected Systems (ICS) which are grid-connected generation systems and Self-Contained Systems (SCS) which are scattered and often mobile depending on the local needs and they are not connected to the national grid. The current potential of energy producing resources and the exploited share is presented in table 6 of section 'Energy Demand Scenario'.

At the moment, there are three prime institutions under the Ministry of Water, Irrigation, & Energy (MoWIE) namely Ethiopian Electric Power (EEP), Ethiopian Electric Utility (EEU), and Ethiopian Energy Authority (EEA) (see section 3.2.5.1). Based on the figures regarding the Ethiopian energy sector created in chapter 3, the following graphic represents the current status of electricity development in Ethiopia (see fig. 55). Until recently the Government of Ethiopia (GoE) had a monopoly over the energy sector which is an example of a preset rule in a socio-technical setting. It is an established way of societal function that was running in the energy sector of Ethiopia. However, with the introduction of GTPs and very ambitious national targets, the tensions in this established regulation showed up and the GoE realized the necessity of involving the private sector in the country's energy business in order to achieve the targets. Further discussion proceeds on such intra-level socio-technical regime tensions in the successive chapter.

Table 4 in chapter 3 briefly express the electricity access figures in Ethiopia as of 2015 which gives us a prospect of the electricity sector as a whole and in future advancement in those figures with their rapid development have to be backed by strong national policies which will create a convenient environment to sustain the ambitious targets made in the country's Growth and Transformation Plans (GTP). With the execution of GTPs leading to heavy infrastructure development in the energy sector, the generation profile of the country has started to look more diverse as the national government is positively inclined towards the Paris Climate accord and with the national goals of becoming a climate resilient economy, chances of achievements are high as per the author. The current status quo on total energy demand is presented in the figure below. (see fig. 56).

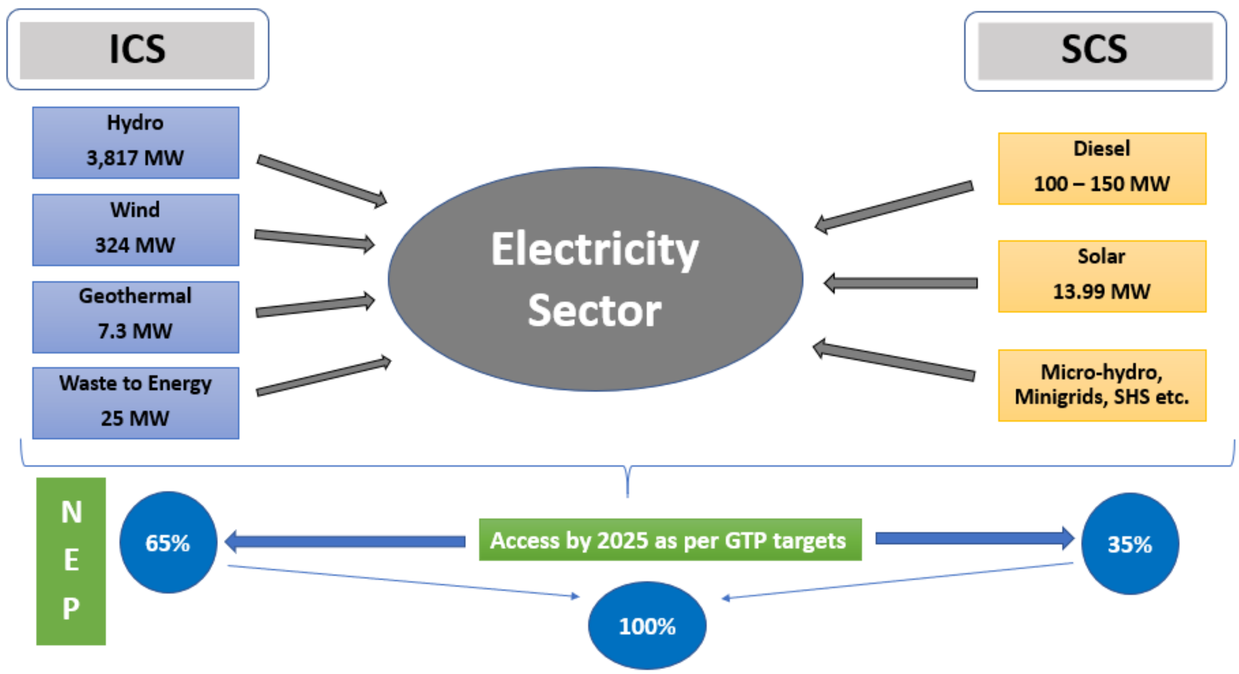

Figure 55: Ethiopian Current Electricity Sector Overview, Source: Own compilation from different sources

As per the section 'geographical contour' in chapter 3, because of the presence of large amounts of plateaus and mountains, it is not very suitable physically and viable economically for the national grid expansion. Therefore, the government has decided on scaling up the self-contained systems on an independent basis as well as encourage the private sector to involve in the electricity production and distribution business. New investments are needed to support comprehensive strategies encompassing grid and off-grid solutions, private sector participation, and encouragement to utilize the country's vast renewable energy resources. Therefore many international organizations such as ESMAP, GIZ, Danish Government, EUEI PDF/GET.pro, World Bank, and many more are also lending their support. (ESMAP 2018)

The previous chapters have already observed the desire of government regarding the full electricity access plans to its citizens. According to the Ethiopian Ministry of Water, Irrigation, and Electricity (MoWIE), the country now has 4,300 MW of total installed power generation capacity and as well as there are more than 9,000 MW of projects under construction and more than 3,000 MW of projects are under preparatory phase of discussion and planning. (Xinhua 2017) The plans of expansion of the national grid under the GTP II is also provided in table 6, chapter 3.

The major sectors in the consumer side in the country are household, agriculture, industry, and services and others. The following graphic displays the share of electricity demand per aforementioned sectors as of 2015 in the unit of PJ (see fig. 56).

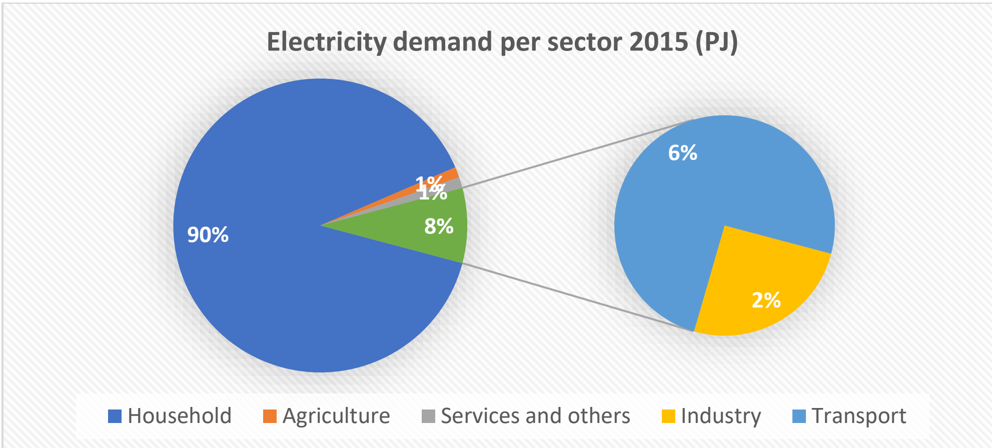

Figure 56: Share of electricity demand per sector in Ethiopia, Source: Own compilation from different sources

Note: For graphical representation, the values are rounded off to (Household 89.2 % ~ 90 %, Rest 10.8 % ~ 10 %).

Now that the two distinctive regimes in the Ethiopian energy spectrum have been described, the successive section goes further down in the socio-technical setting to the micro level and identifies the new technological niches that have emerged and developed/developing in Ethiopia.

4.2.3. Technological Niches in Ethiopian Energy Sector

As learned in the analytical framework, the development of new technologies takes place as niches, often to address the issues created at the dominant socio-technical regime level. As Geels and Schot mentioned that because of its weak structuration, high ambiguities, and low consistency the niche can easily be influenced by the socio-technical regime and landscape. Sometimes, there are multiple niches in development simultaneously. In the previous section, two distinctive regimes have been identified namely traditional biomass and electricity regime. These two incumbent sectors have predominantly encompassed the energy sector of Ethiopia.

Now, the rule and nature of transition are that it is a process of continuation and won't stagnate for long even though at meso-level, the stakeholders at socio-technical regime would always wish and try to keep the establishment unchanged. The following novel niches/radical changes according to the author are functional in the context of Ethiopia.

Since the diversification of the country's prime target to tackle the seasonal problems and potential climate change impact associated with hydroelectric stations as a lion share of electricity demand is fulfilled by hydropower (International Hydropower Association 2017), new renewable energy conversion technologies for different energy resources like wind, solar, geothermal are acting as the technological niches. These novelties were already briefly explained in the previous chapters along with their installed capacity and potential generation in the future. This will release the sole burden of the electricity generation from hydropower and increase the diversity of the energy mix. The Government of Ethiopia has realized this and taking important steps towards addressing this issue.

Along with that, independent systems for electricity generation such as solar home systems (SHS), small-scale micro-hydro and mini-hydro power plants, cogeneration units coupled with sugarcane factories, new efficient batteries for storage, efficient lamps for lighting, energy efficient household appliances and industrial machinery are also the novel technological niches in the same framework of electricity sector. The absence of grid because of various social and geographical factors has resulted in keeping the country's electricity access rate at low levels. These above-mentioned new technologies can help provide firstly, the access of electricity through off-grid electrification, secondly, some mini-grids will also have the opportunity to merge with the national grid (when available) to contribute to the energy sector in future. However, there must be a clear scheme or regulation regarding the grid interconnection with mini-grids in future stating if the mini-grid operators get compensated for shutting down or the mini-grids will keep running for example.

Energy efficiency also has the major potential in developing countries, as one of the solutions to the global call for energy consumption reduction is energy efficiency. Ethiopia is also in the same cluster. The penetration of new and efficient lighting and appliances will not only decrease the energy consumption units in the household sector but also reduce the cost of electricity consumption. Same goes for industrial lighting, appliances, and machinery.

On the other hand, when it comes to the other energy sectors, as a major portion of the population is rural-based (The Africa Report 2018), it is very much dependable of the biomass sector as identified in the previous section of the socio-technical regime. The technologies which have been acting or has the potential as technological niches are energy efficient cookstoves, the introduction of household biogas system using animal dung and human feces as substrates, solar cookers as the country enjoys a generous amount of sunlight throughout the year, bio-briquettes as cooking fuel instead of charcoal. These measures can address the problem of indoor pollution. Studies show that in Sub-Saharan Africa countries, the indoor air pollution comes in the range of 3.7 % to 6.6 % in terms of burden of disease which ranks in the cluster of threats like HIV/AIDS and malnutrition. (Negash and Riera 2014)

The transport sector could use energy efficiency, fuel blending, for example; E10 in transport, electric mobility as new technological niches. Although fuel blending practices are existing in the country (Abiye 2011), electric mobility is far-fetched. UNDP in 2013 had a pilot program for electric vehicles in Ethiopia, however, the latest data of that program couldn't be found. (UNDP 2013) Apart from that energy efficiency in the transport sector is also important in terms of pollution. During the visit to the country in 2017, the author had noticed the outdated vehicles emitting a heavy amount of smoke and hence making Addis-Ababa which is the capital city of Ethiopia very much polluted. As of November 2018, the World Air Quality Index says that the pollution level in the capital is 'Moderate'.

4.3. Dynamics and Typology of Transition in Ethiopian Energy Sector

The degree of scalability of innovation is influenced by the interactions between the three levels (socio-technical landscape, socio-technical regime, and technological niches). The entry possibilities and retention of novel niches in the socio-technical regime are dependent on the consistency or stability within the regime. At times, due to alterations in global and/or national trends at landscape level influence, the well-established regime to change and this phenomenon also creates room for the novel developed niches to rise up and function at regime level and sometimes replacing them. In the case of Ethiopia, the landscape actors which were identified in the previous section have an important role to play in the country's socio-technical shifts.

Usually, the entities in the dominant regime resist against niche developments. Therefore, the more stable the regime will be, the stronger resistance will be projected for new technologies. The windows of opportunities often open at regime level creating chances for the niches to breakthrough. There are two ways in which the destabilization in the regime occurs as described in chapter 2. One, it originates from the pressure exerted by the socio-technical landscape factors and the other is due to the internal regime dynamics.

The internal momentum of the niches depends upon the factors like modified price/performance ratios and degree of development which are often supported by strong external actors (global trends and demands) to increase the functionality of innovations. Once the niche momentum is established and its development reaches feasibility, it can exert influence on the regime through bottom-up forces. (Kamp and Bermúdez Forn 2016) As presented in the previous paragraph, intra-level interactions within the regime level even in the absence of any external pressures is another form of dynamics at socio-technical regime level. This process is mainly an internal adaptation and reconfiguration of the regime actors even during they are stable to reorient themselves along the trajectories according to the current demand of the society.

The figure below (see fig. 57) summarizes the dynamics of the interactions between different levels of socio-technical transition as discussed in the analytical framework of chapter 2.

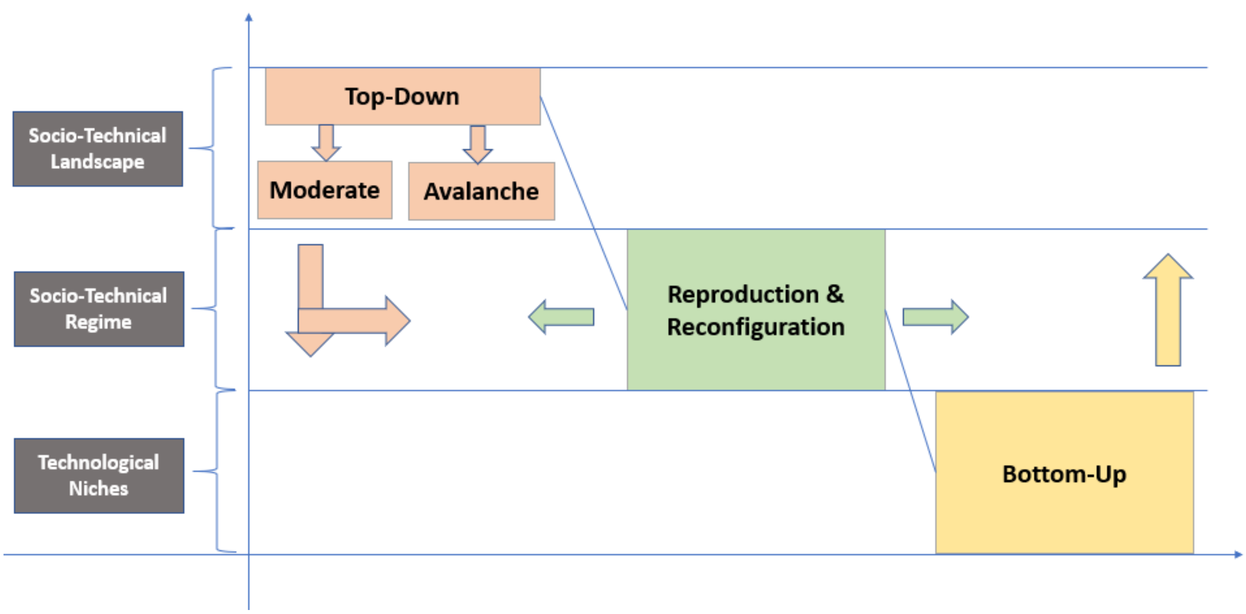

Figure 57: Dynamics of socio-technical regime mapping, Source: Own illustration

Considering the case of Ethiopia, where the chances for bottom-up forces enabled by new technological niches are very slim due to very little research and development work in the energy sector is existing yet. Most of the new niches come into the country through the best practices from developed nations in terms of technology transfer. Therefore, in the following sections, the author discusses the top-down disruptive changes along with intra-level reproduction and reconfiguration based on the analytical framework presented in chapter 2, section 2.4.

4.3.1. Top-Down Approaches

In previous sections of chapter 3, all the future installment targets, policy goals, and programmes are presented which are supporting this non-linear system change which otherwise known as 'disruption' by the moderate pressure exerted by the landscape to bring about certain necessary reorientations at regime level. The two categories of top-down forces active in Ethiopia are identified in the analytical framework are as follows.

4.3.1.1. Moderate Transformation

- ***Climate Change and Natural Disasters:**
  Internationally there is a steep inclination with regard to a momentum shift from conventional fossil fuel economy to a more climate-friendly green economy. With this global trend in place, Ethiopia is one of the 16 countries out of the 197 that have signed the Paris Agreement according to the latest study which has shown goodwill by taking steps and defining ambitious national climate action plans to realize their pledges (Claire Stam 2018) Not only plans, but the country is also moving in the direction of diversifying its energy mix to address the problems associated with hydropower due to climate change.
  * This factor is considered as a process, not in terms of the immediate effect of natural disasters.

- **International Oil Prices:**
  The fluctuations in the international fuel market have insofar crippled the country by sucking up almost 80 % of the foreign currency reserve annually. This led to the country's growing interest in finding local fuel substitutes and fuel blending options as described in the respective chapters previously.

- **Poverty (Country level):**
  About 44 % of the population in Ethiopia are living in poverty and it is counted as one of the poorest countries in the world. (Brandi Gomez 2017) However, with its rapid development of maintaining a growth rate at nearly 11 % since the last couple of years, Ethiopia is aiming towards becoming a middle-income status country by 2025. (USAID 2018b) In order to achieve its ambitious goals, the government along with the aid from international entities is trying to enable woman empowerment in the field of biofuel and bio-briquette productions locally which creates both energy resources alternatives and financial improvement. Together with that, reduces the indoor pollution rate saving many lives.

- **Education and Skilled Labour Shortage:**
  Advancing rates of education level in Ethiopia is a very good sign for both the country and its population. As per the author, with good education comes good competitive skills which on one hand will increase employment rates and on the other hand, it will have the potential to develop new technological niches eventually. The best strategy is to invest a lot in the education sector because the return on investment is pure development for the country.

4.3.1.2. Avalanche Transformation (De-Alignment and Re-Alignment)

- **Political Instability and Corruption:**
  The increasing number of public protests and anti-government activities were quite high during 2015 – 18. The rule of multi-ethnic coalition party along with its poor performance with respect to the global corruption index had witnessed quite a political turmoil leading to the declaration of a state of emergency twice. (Aljazeera 2018) Such events have undoubtedly delayed the development process in the country and hence the process of transformation is creating stagnation at the regime level.

- **Availability of natural resources:**
  From the beginning of the thesis, it has been established that Ethiopia is rich and fulfilled when it comes to the availability of natural resources. However, the biggest concern is tapping them well both in an economic and environmentally friendly way. With the ambitious goals and the execution of the policy targets, the pressure from the landscape is visible on the regime as more and more integration of new technologies is witnessed by the country.

- **War and Terrorism:**
  Few unsuccessful planning regarding antisocial activities in Ethiopia by Somalia-based extremist groups has been reported. Therefore, Utmost vigilance is necessary because of the large presence of international community and the headquarter of African Union is also in Addis Ababa. Such terrorist groups make the entire East African region dangerous. (UK Government 2018) There have been many incidents of internal conflicts lately, however, the last major war was fought between Ethiopia and Eritrea in 1998 over national pride and territorial integrity claiming many lives and displaced even more. (Patrick Gilkes 2005) Such situations can abruptly change societal functions. More recently, Ethiopia and Egypt are at loggerheads over the construction of a new dam on the Blue Nile. Many meetings for negotiations have been conducted and there is a hope that the situation will be solved without any wars. (Lazarus and CNN 2018)

4.3.2. Reproduction and Reconfiguration Approaches

Two distinctive regime actors are identified in the previous section for this study namely ‘Traditional Biomass’ and ‘Electricity’. While for its overall energy demand, Ethiopia relies on the traditional biomass regime, however, when it comes to the electricity sector, hydro resources take the major share of the burden. This scenario, however, is changing as this intra-level contestation creates a rhythm for the dominant actors at the regime level to go along with the development.

- **Poverty (Local level):**
  With the popular correlation between societal poverty levels with the utilization of traditional biomass as the primary energy source in place, the Ethiopian energy sector is fighting hard to change the status-quo. It is the part of an upgradation process of utilization of fuelwood for cooking and baking demands, however in a more efficient way such as by mixing fuelwood with charcoal, dung cakes with branches, leaves, and twigs (BLTs), bagasse from sugarcane, and introduction of biogas technologies to use the cattle dung along with human feces alternatively. (Geissler 2014) Same goes for the electricity services as affordability and willingness to avail grid connection as well as to pay for the services are the concerns.

Kerosene lamps, small battery-operated torches are insofar accountable for lighting demands in the low-income households of the country where access to the grid is not existing. On the contrary, the urban sector is mostly grid-connected, but affordability is still considered to be an issue.

- **Availability of resources (Local level):**
  While poverty dictates the ability to avail the resources and services, their availability locally is definitely a matter of concern. Corruption is perceived to be rooted till lower levels of the public sector in the country. (GAN Integrity 2017) This frequently poses a challenge regarding the equal distribution of available above-mentioned resources. As per the rule of economics, the prices of goods and services increase when the demand is more, and the supply is less. It holds true for both the cases of traditional biomass and electricity. Therefore, the government, first of all, has reformed the anti-corruption laws and secondly, by bringing in more and more ambitious targets under its national Growth and Transformation Plans (GTPs) to increase the resource availability.

- **Regional Ethnic Conflicts:**
  Although the ethnic conflicts could be considered in the socio-technical landscape, however, usually it starts small before spreading all over the nation. Often these conflicts result in very difficult situations for any actors at the regime level to function normally. Regular protests, violence, and suspension of national services like telecom (telephone and internet) create chaos and hence leading to quick alterations by regime actors according to the situation. As described previously, there has been a mass anti-government movement running during 2015 - 18 in the country which delayed the process of development work.

- **Scalability of National Projects and Policies:**
  The most frequent practices in any country are the improvement on the scalability of projects and the policies supporting them. From time to time, it is necessary to develop the new infrastructure either in form of new projects or renovations. This process also occurs when the regime is stable but going on through some reconfigurations within itself to enable incremental and cumulative changes along its trajectories. In the case of Ethiopia, many projects which were under GTP I further scaled up under GTP II, for example, off-grid solar technologies in Ethiopia. (World Bank 2016)

Based on the dynamics explained, the author now puts his own understanding of it with the help of the following representation (see fig. 58). All the arrows across the levels are pointing towards the direction of movements along the trajectories. The orange colour represents the top-down forces and the niches associated with them, whereas the green colour represents the reorientation forces within the regime level and the niches associated with them. Finally, the yellow coloured bottom-up forces represent the direction of niches towards the regime. The dotted boundary around the bottom-up box indicates the inability of voluntary bottom-up movement of niches due to the lack of research and development activities in Ethiopia.

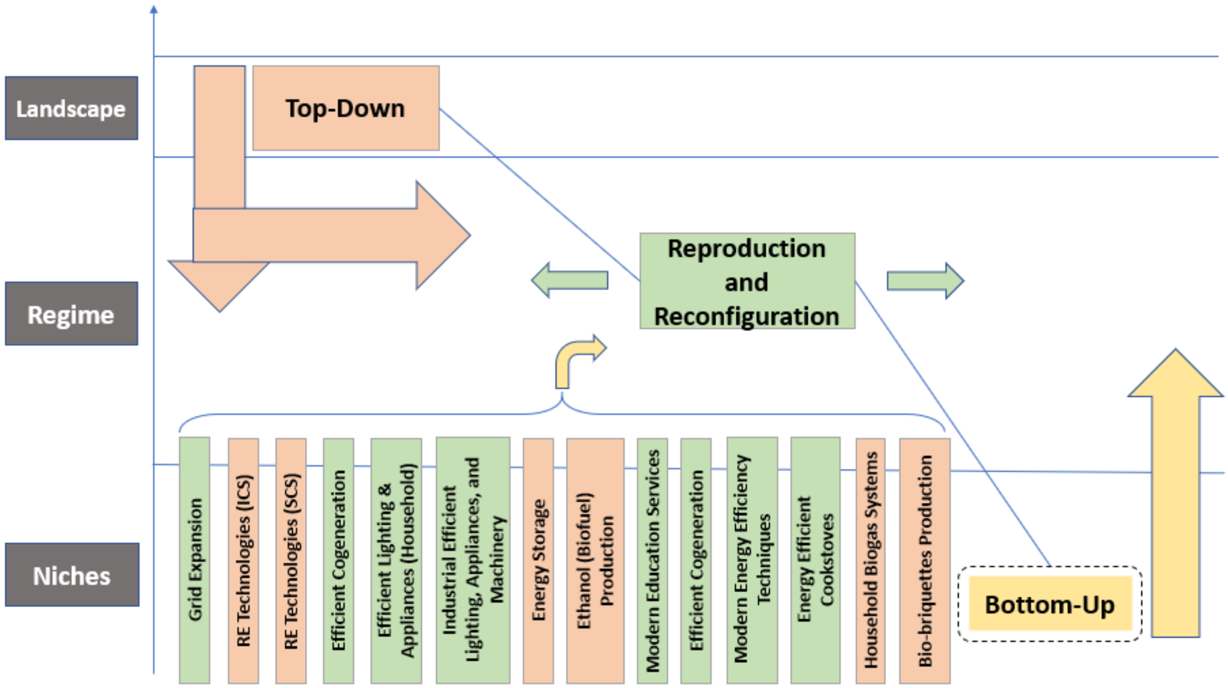

Figure 58: Dynamics of transition in Ethiopian energy transition, Source: Own illustration

4.4. Latest Developments in Ethiopia

This thesis revolves around the times ranging from post-1950s till the end of the first quarter of 2018. There have been significant changes since the beginning of 2018 which are not covered in this study. Although the author has integrated some relevant information from recent events where they were necessary. Some of the important events after the first quarter of 2018 which are somehow related to future scopes of this study will be presented in this section.

In the wake of 2018, the political imbalance was still alive. The anti-government unrest led to the resignation of Prime Minister Hailemariam Desalegn. Later in April 2018, an ethnic Oromo leader Dr. Abiy Ahmed won and became the head of the ruling party EPRDF and hence became the third prime minister of the federal republic of Ethiopia. In May - June, the newly formed government officially lifted off the state of emergency and launched many comprehensive programmes of political reforms both of national and international stature. Along with that released thousands of political prisoners.

In July marked the remarkable event in the history as the reconciliation between Ethiopia and Eritrea ending a long border dispute. Furthermore, in October, signing a peace treaty with the separatist Ogaden National Liberation Front (ONLF) and it ended a long 34 years of armed rebellion in the country. (BBC News 2018) In the same month, the Ethiopian parliament elected Sahle-Work Zewde as the first-ever woman president of Ethiopia. Along with that, Ms. Meaza Ashenafi was appointed as Ethiopia's first woman president of the Federal High Court of Ethiopia. Not only that, the new prime minister of Ethiopia has made new appointments of women in over half of his cabinet. (The East African 2018)

Table 7 in chapter 3 lists out all the ongoing and new projects under the country's Growth and Transformation Plan (GTP). According to Xinhua News Network, the power coverage in Ethiopia recently overtook 57 % with the number of households connected to the national electric power grid has increased to 2.8 million. The World Bank pointed out that the country has the second highest available power generation capacity in the Sub-Saharan region of the African continent with vast potential in other untapped sectors like wind, solar, and geothermal. (Xinhua 2018) The government of Ethiopia (GoE) is looking forward to integrating more and more renewable energy resources into its energy mix as described in previous chapters. There are factors like policies, framework, willpower, CRGE deadline of 2025, international help in terms of grants and technology transfer; all working under a common goal of development.

In March 2018, Ethiopia and Russia have reached an agreement to develop nuclear energy in Ethiopia collaboratively. Russia also plans to create an Ethiopian center for nuclear science and technologies based on a Russia-designed research reactor. (broken 2018) Although nuclear energy generation doesn't harm the environment like fossil fuels do, it would be interesting to see Ethiopia developing its economy by availing the nuclear services and technology transfer from Russia amidst all the vulnerability associated with nuclear power.

In 2017, Ethiopia overtook Kenya by achieving the status of the largest economy in East Africa. Soon the state-owned and controlled telecom, electricity, and also the national airline will be opened up for foreign investment which indeed will boost the country's economy. (Sevenzo and CNN 2018)

These events are certainly in favour of the development run of Ethiopia with its ambitious goals according to the author. These latest events show a positive sign that the country is in good hands at the moment. Resolution of international and national political disturbances, improving gender equality at the centre, and accelerated efforts towards energy system diversification are indeed some promising steps taken by the newly formed government under its new leadership. The better execution of the plans is what the country needs now in order to see the transition from an agrarian economy to climate resilient green economy in near future.

Chapter 5: Summary, Conclusions, and Recommendations

5.1. Summary and Concluding Remarks

The thesis started with the hypothesis that 'renewable energy sector expansion is possible in Ethiopian energy system'. The idea was to analyse whether one of the poorest countries in the world like Ethiopia could count on the available abundant renewable energy resources in order to diversify its energy system. Also, to further understand this transition and its dynamics with the help of socio-technical analysis. Therefore, the MLP theory was chosen for the task. Based on the study done throughout the process of writing this paper, the following conclusions are drawn:

Ethiopia is socially, demographically and environmentally divergent country with a population of over 102 million situated on the horn of Africa. According to the World Bank, Ethiopia still remains as one of the poorest economies in the world in spite of a remarkable growth rate of nearly 11 % throughout a decade now as per African Economic Outlook. Ethiopia's economy is mostly agriculture based and with high ambitious goals set by the national government, the country is striding forward to become an agricultural led industrial economy. Ethiopia is rapidly growing and is one of the frontrunners among its counterparts. With the increase in industrial development, comes the incredible rise in the power demand in the country. Currently, the power sector is highly dependent on hydropower which faces seasonal problems. Ethiopia was one among the first daring signatories of the Paris climate accord at COP 21 in 2015. Therefore, it calls for a development pathway which will be green and climate-friendly under its Climate Resilient Green Economy strategy by the year 2025.

Multilevel Perspective (MLP) theory has been employed to interpret the process of Ethiopian energy system transition. MLP theory worked across three different levels in a socio-technical setting. Landscape lies in the macro-level and overlooks at the whole system from the top. In the middle meso-level, lies the socio-technical regime which is the driving strength of the whole system. At the lowest micro-level, technological niches reside which is the zone of new developments and inventions. At this level, new technologies are invented and wait for the opportunities to a breakthrough at the regime level. These breakthroughs occur due to different interactions of actors at all three respective levels. The types of dynamics are top-down (moderate and avalanche) which gets triggered when there is a pressure from landscape on regime, reconfiguration and reproduction occurs when there is an intra-level tension in the regime and certain things change to realign the trajectories, and the last one is bottom-up force which defines the breakthrough of niches into the regime to replace outdated actors with new technologically advanced ones.

Approximately 34 % of Ethiopia's population out of over 102 million live below the poverty line. The population is majorly rural-based mostly depending on agricultural activities and is dependent on the traditional biomass resources. Also, the overall energy related demand is being met by biomass resources in both rural and urban areas. According to the Ministry of Water, Irrigation, and Energy, household sector consumes around 92 % of total biomass energy, whereas agriculture consumes 3 % and other services takes the last 1 % respectively. The ambition and priority of the government now is to become a middle-income status country and the small achievements in industrial development have witnessed a 4.6% decrease in the consumption levels of biomass resources.

On the other hand, the share of petroleum fuels and electricity have escalated from 4.8% to 6% from 1996 to 2010. It is estimated by the ministry that the demand for 2030 shows that biomass demand will decrease to 71.6 % by the year 2030 when an increment of 22.6% and 5.8% will be seen in the petroleum and electricity sectors respectively.

The overconsumption of natural biomass resources due to the lack of alternatives have caused serious damage to the environment creating disbalance in the eco-system. Such factors contribute to seasonal changes with recurrent droughts in the country and eventually facing the bigger threat in form of climate change. Therefore, the government is now focusing more on the integration of other alternatives, for example, biogas, efficient cooking stoves, bio-briquettes, ethanol etc. to make the system more diverse and hopefully with the availability of other alternatives the sole pressure on traditional biomass sector will be reduced and the eco-system balance can be restored.

The overwhelming competition about 'food vs fuel' has also become an issue of debate for the government as a result of the promotion of extensive bio-fuels expansion strategy. Consequently, the government had downsized its efforts during the first quarter of this decade. However, with proper management in the production and distribution of crops, this problem can be addressed. Not only biofuels could be used energy or electricity production, but it is also another form of employment for farmers and additional income source for many landowners.

The electricity access in the country is also limited. As of 2013, only about 23 % of the population was connected to the grid and new figures as of 2016 show that the numbers have increased to about 42 % after the commissioning of Gilgel Gibe III hydropower project with the installed capacity of 1,870 MW. Ethiopia majorly relies on hydropower resources whose renewable status although is debatable globally, but at least it is not as harmful as conventional power systems. There is a lot of pressure on the hydropower resources to meet the country's electricity demand. In 2013, according to the ministry, electricity consumption accounted for 33 % is by households, 40 % by industries and 27 % by the service sector. The same figures are assumed to be valid hitherto. However, the per capita power consumption is still considered low. One of the major concerns in the power sector is also the expansion of transmission lines which will enable the increasing rate of installed capacities to be accessed by both small- and large-scale end-use customer. With the expectation of 30 % annual increase in the country's total electrical demand, Ethiopia is coming up with new strategies under its new electrification plan launched in 2017.

Regarding the energy demand scenario, with the help of the results from LEAP analysis done by Mr. Md Alam Mondal and group, two different scenarios have been projected till the year 2030. Under the business-as-usual or reference scenario following up with the historical trend. By 2030, there will be an increase in the Ethiopian population up to 129 million, however, the average family size is expected to decrease to 4.4 members per family. The total energy demand is predicted to escalate from 1358 PJ in 2012 to around 2120 PJ in 2030 with the industrial sector seeing the largest share under business-as-usual scenario. This prediction supports the goal of making Ethiopia's economic sector more industrialised. Followed by that, agriculture, transport, and other service sectors come in sequential order in terms of energy demand. Residential energy demand, especially in the rural sector, will increase significantly as, over the time, they will come under the national grid or will have off-grid solutions to gain electricity access.

Consequently, under the alternative scenarios, three cases were considered namely universal electrification scenario, efficient lighting scenario, and improved cookstoves scenario respectively. They are based on the government's priorities regarding enhancing energy efficiency, energy access, and reduction of GHG emissions under the objective of becoming a climate resilient green economy by 2025. The improved cookstove scenario assumed a more rapid diffusion of improved cookstoves in the Ethiopian households, universal electrification scenario assumed more rapid expansion of the national grid will be facilitated to increase the rate of electricity access to the population, and the efficient lighting scenario took a more rapid diffusion rate of efficient lighting units like compact fluorescent lights (CFL) and tube lamps into consideration which are 70 % and 30 % more efficient than incandescent bulbs respectively.

According to the LEAP analysis results compared between these two scenarios (reference and alternative), 241 PJ (13.4 % savings) of energy will be saved in 2030 as compared to the reference scenario under improved cookstoves scenario. The growth rate of electricity demand will be reduced to 3.4 % annually under the efficient lighting scenario as compared to the annual growth rate of 7.6 % in the reference scenario. Lastly, the difference between the reference scenario and universal electrification scenario in terms of total electricity demand is about 5094 GWh.

Nevertheless, this study also assessed the country's energy mix from a sustainability point of view which included the system imperatives of economic development and growth, security and access, and environmental sustainability. Apart from hydropower being so dominant in the country, there is plenty of potential in wind, solar, and geothermal resources. Ethiopia is already tapping wind power with present installed capacity of 324 MW. New 100 MW solar plant's tender has been passed and is currently under construction. 7.3 MW of geothermal plant is currently functioning and there are plans in progress to expand this sector. In addition to that, a 25 MW waste to energy plant was recently commissioned near the capital Addis Ababa and many sugar factories are improving their cogeneration units to produce power. Off-grid independent systems such as micro-hydropower plants and solar home systems as well as small-scale solar PV plants are also coming up in the country internally and with the aid of international organizations like GIZ EnDev (also involved in improved cooking stove programme).

The dimensional analysis of Ethiopian energy system transition enabled the identification of all the actors responsible according to the socio-technical levels they belong to. Different indicators define their dynamics which eventually set the tone for the socio-technical transformation. The landscape puts pressure on the regime in two ways; moderate and avalanche. The moderate pressure-oriented transformations include climate change, oil prices, poverty, and lack of education and skilled labour. Whereas, the avalanche transformations include political instability and corruption, availability of natural resources, and war and terrorism. These pressures create or have the potential to create differences in the established regime and open windows of opportunities for the niches to take over.

Regarding the socio-technical regime, two distinctive options were chosen after thoroughly studying the country's energy portfolio. Traditional biomass regime encompassing the whole energy spectrum and electricity regime dealing with the country's electricity profile. The trajectories at this socio-technical level of the country realign themselves by the process of reproduction and reconfiguration. In this regard, the local level poverty, local availability of resources, regional ethnic conflicts, and scalability of national projects and policies define the internal movements to keep the transition running. There are no prospects for voluntary bottom-up movement of forces to take over in the regime due to the lack of research and development activities in Ethiopia for radical changes to develop.

This study gives projects an image of Ethiopia's energy system transition in the direction of penetration of more new renewable energy technologies in its energy mix to take off the pressure from hydropower sector to meet the electricity demand and implementation new technologies and efficiency techniques in the country's traditional biomass sector.

5.2. Recommendations and Future Scope

1. **Increasing installed capacity sustainably:**

Ethiopia's focus towards the development of other renewable resources conversion technologies is going to be very beneficial for the country. The encouragement other renewables will be instrumental for the capacity development and diversification of the energy mix which is quite crucial as it will reduce deforestation, land degradation, and erosion like problems. Therefore, it is recommended to ensure the development of a more diverse energy system to reduce the big gap between energy demand and supply.

2. **Explore other renewable alternatives:**

With the objective of diversification of the energy system, Ethiopia has many other potential alternatives such as about 10 GW of geothermal resources, 100 GW of wind resource and yearlong sunshine to exploit. Therefore, it is recommended that Ethiopia should take the opportunity to invest more on these renewable resources to develop solar and wind farms, heat extraction capacity from geothermal resources so that, the pressure from hydropower alone to run the energy sector could be released. As well as to reduce greenhouse gas emissions and achieve climate resilience.

3. **Good practices on project management:**

It has been noticed that projects often failed due to mismanagement and poor handling, for example, the first phase of the national biogas programme. Therefore, it is recommended to reduce the risk of failure and eventually jeopardizing the whole GTP targets, the government should pay serious attention during all the phases of planning and construction of the new capacities being installed. Proper evaluation, employment of skilled professionals, efficient use of time and finances, and maintenance of the installed systems are some basic rules to be followed. The government should take the responsibility of looking over the construction parameters of every project for their very minimum negative impacts and to be constructed in a sustainable manner.

4. **Ensure electricity access to all:**

According to the world bank data as of 2016, Ethiopia is one among top 20 largest access deficit countries with only about 42 % of electricity access. Lack of well-spread grid-connections has been identified as one of the major barriers in providing electricity to the people in Ethiopia. The reasons behind the problems were geographical, institutional, financial, and sometimes social (willingness to avail grid services). Therefore, it is recommended that proper planning and execution for grid modification and expansion should be achieved with effective policies, good regulatory frameworks, and solid financial backing. Apart from that, off-grid technologies are also to be encouraged in the places where grid-connection hasn't reached. Such standalone systems should be developed in a technically compatible way to have future possibilities of grid interconnection and will create opportunities for 'Prosumerism' in future. However, clear policies on this national grid – standalone systems interconnection are recommended to be formulated to secure the future of the standalone systems. Expansion and interconnection of transmission network with other countries also need to be scaled up to improve foreign trade.

5. **Employ energy efficiency measures**

The demand scenarios illustrated the huge gap between the electricity demand and supply and it was also noted that the country is facing almost 20 % of transmission and distribution loss in the electricity sector. Other than that, in the overall energy sector, as the population is majorly reliant on woody biomass for its daily cooking and heating needs and the trend will continue in future. However, there is a small and gradual shift to electricity in the urban areas for the cooking needs, which will add up to the total electricity demand. Therefore, it is recommended to launch policies on overall energy efficiency and ensure its thorough execution in all the sectors.

6. **Skill development and good education**

With low literacy levels and a shortage of skilled personnel, Ethiopia has to largely depend on international aid in terms of money as well as technological expertise for the country's national projects, for example, recruitment of foreign nationals in significant project positions. This factor was also seen in the form of lack of novel niches in the socio-technical analysis of the country's energy system transition. Therefore, it is recommended that the government shows positive efforts towards proper education and skill development programs at a rapid and large-scale, Ethiopia could be benefitted largely in the long term as with better education and skills the country will develop at a much faster rate.

7. **Ensure affordability**

After the poor performance of the first national biogas program due to improper management and structuration of the program, the second phase marked a difference. It has been proved that with steps like providing subsidies for compensating the initial installation costs, the affordability and eventually the acceptability. Therefore, it is recommended that possible options for subsidies should be explored at the time of commencement of diffusion of new technologies for their scale up.

8. **Regulatory reforms**

In the Ethiopian energy sector, international agencies such as GIZ and the World Bank and many others are taking leading roles in the state-owned projects. Coordinated steps by the government along with these international partners are recommended in the formulation of well-structured policies and regulations such as proper budgetary allocation to the projects, creating favourable conditions for private sector involvement, improving ease of doing business for foreign investors and so on in order to drive the national projects successfully by taking lessons from proven good practices around the world.

9. **Citizen engagement**

Creating awareness has the potential to solve a lot of problems even before they start to occur. Basic knowhow on the conservation and efficient utilization of energy resources, implementation of 3 'R's; reduce, reuse, and recycle, sustainable used and waste reduction will potentially make a lot of difference. Therefore, it is highly recommended to introduce these practices and engage the public through ads, campaigns, etc. to improve the overall development of society.

10. Coordination and cooperation

With projects being developed at different places of the country, often they are delayed or terminated due to several factors. One among them is lack of coordination. Therefore, proper coordination, cooperation, and communication are required between the stakeholders to ensure the timely completion of projects.

Finally, the author would like to encourage researchers to go for more research activities in developing regions of the world. Lack of technical know-how, financial limitations and attention to other immediate problems have kept countries like Ethiopia to develop in one way or the other. More research activities will enable better formulation of policies and eventually their implementation to contribute towards its development. Future scopes in author’s point of view are to look for further conditions and risks beyond the energy system during or followed by the transition. The climate impact assessment could also follow as one successive topic for this socio-technical transition. More alternative scenarios could be assumed for the study and comparisons with business-as-usual cases of Ethiopia.

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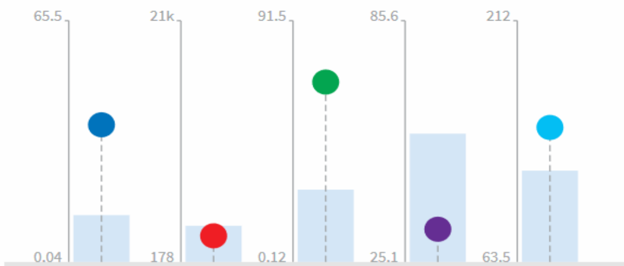
Annexes

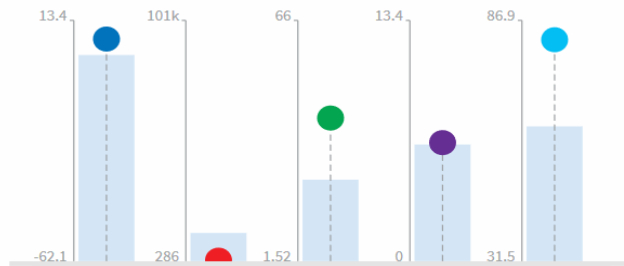
Table T1: Socio-economic facts from Ethiopia comparing to world averages, Source: (USAID 2017)

Hunger and Food Security



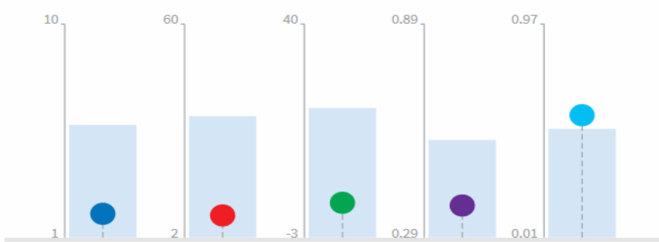
Indicator Name	Value	World Avg.
Agriculture, value added (percentage of GDP)	37.2	12.7
Cereal yield (kg per hectare)	2.5k	34k
Employment in agriculture (percent of total employment) (modeled ILO estimate)	68.2	27.5
Global Food Security Index (0-100, 100 = best environment)	33.3	57.3
Net production index - agriculture	146	120

Economy



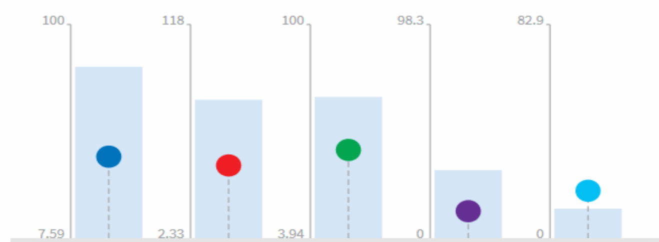
Indicator Name	Value	World Avg.
GDP growth (annual percentage)	7.56	2.54
GDP per capita (current $US)	707	12k
Gross fixed capital formation (percentage of GDP)	39.8	23.3
Income share held by lowest 20 percent	6.6	649
Labor force participation rate, total (percentage of total population ages 15+) (modeled ILO estimate)	82.5	62.5

Democracy, Human Rights, and Governance



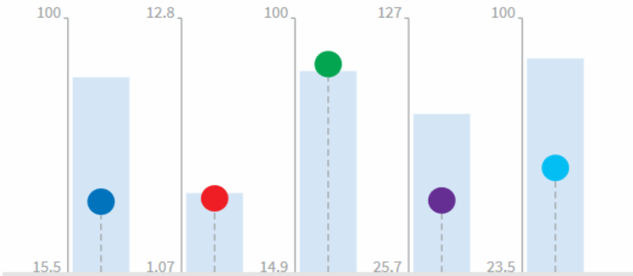
Indicator Name	Value	World Avg.
Bertelsmann Transformation Index: Political Participation: Free and Fair Elections Score (1-10, low-high)	2	5.75
Freedom House: Civil liberties, aggregate score (0-60, higher is better)	8	35
Freedom House: Political rights, Aggregate score (0-40, higher is better)	4	23.1
Rule of Law Index- Overall Score (0-1, higher is stronger rule of law)	0.38	0.56
Varieties of Democracy, political corruption index (0-1, higher is more corrupt)	0.56	0.5

Environment and Global Climate Change



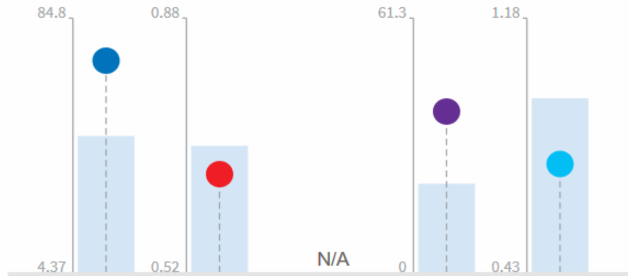
Indicator Name	Value	World Avg.
Access to electricity (percentage of population)	42.9	81.7
Climate Risk Index Score	41.7	77.1
Environmental Performance Index (EPI) Issue Category: Air Quality score (0-100, higher is better)	43.7	67.5
Forest area (percentage of land area)	12.5	31.3
Terrestrial and marine protected areas (percentage of total territorial area)	18.5	11.5

Education



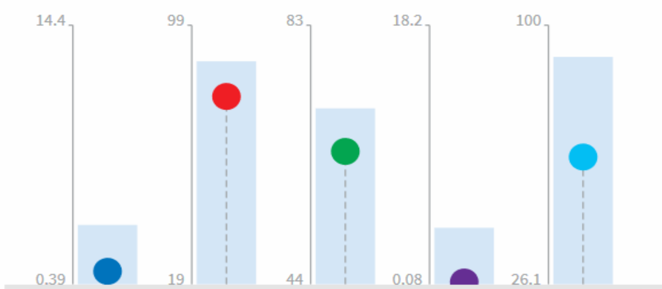
Indicator Name	Value	World Avg.
Adult literacy rate, population 15+ years, both sexes (percentage)	39	80.3
Government expenditure on education as percentage of GDP (percentage)	4.5	4.74
Percentage of teachers in primary education who are trained, both sexes (percentage)	84.6	82.3
Primary completion rate, both sexes (percentage)	54.3	88.6
Youth literacy rate, population 15-24 years, both sexes (percentage)	55	87.9

Gender



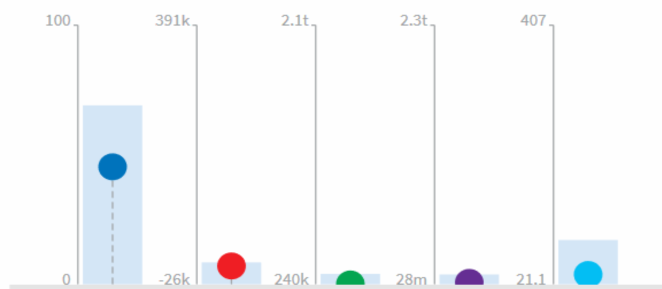
Indicator Name	Value	World Avg.
Employment to population ratio, 15+, female (percentage) (modeled ILO estimate)	714	47.5
Global Gender Gap: Index score (on a 0 to 1 scale, where 0=inequality and 1=equality)	0.66	0.7
Percentage of Individuals using the Internet, female	N/A	62.7
Proportion of seats held by women in national parliaments (percentage)	38.8	214
Youth literacy rate, population 15-24 years, gender parity index (GPI)	0.75	0.94

Health



Indicator Name	Value	World Avg.
Domestic general government health expenditure (percentage of GDP)	1.09	3.6
Immunization, DPT (percentage of children ages 12-23 months)	77	87.8
Life expectancy at birth	64	70.5
Nurses and midwives (per 1,000 people)	0.24	4.04
Pregnant women receiving prenatal care (percentage)	624	90.9

Trade and Investment



Indicator Name	Value	World Avg.
Doing Business: Distance to frontier: trading across borders (higher is better)	45.3	69.1
Foreign direct investment (FDI) inflows ($US millions)	3.2k	8.9k
Merchandise exports (current $US)	2.9b	84b
Merchandise imports (current $US)	17b	85b
Trade (percentage of GDP)	35.8	87.1

Bonus Chapter C1: History of Ethiopia and its Policy-Making

It is believed that people have lived in Ethiopia since very early times. The oldest Aksumite Kingdom dated back to first century BC. Ethiopia is also the oldest independent country in the African continent. The Egyptians introduce the Coptic Christianity in Ethiopia in the 15th Century. Ahmad Gran, a Muslim leader conquered the major portion of the country during that time. During and by the culmination of the 19h century, Ethiopia saw a series of power shifts until Emperor Menelik II took over and led the country through Italian invasion in 1895. Ethiopia was recognized as an independent state after defeating the Italian attempt to possession. The second attempt of Italian accession, however, was successful, and they managed to hold the power in the name of Italian East Africa, combining three separate nations – Ethiopia, Eritrea, and Italian Somaliland. After five years 1936 - 1941, with the assistance of British army, Emperor Haile Selassie I regained the power after defeating the Italians again. Selassie went on ruling Ethiopia until 1974, when a military coup led by General Terefi Benti dethroned him. In just three years, Benti was replaced by Colonel Mengistu Haile Mariam, a Marxist dictator in 1977. Between 1977 and 1979, the country witnessed mass killings of government opponents, also infamously known as 'Red Terror'. (Neil desai 2015)

A Somalian invasion also happened around in '80s which was defeated by Ethiopia with the assistance of Cuba and the Soviet Union. In 1987, Mengistu was elected as president under a new constitution only to be ousted by the Ethiopian People's Revolutionary Democratic Front after 4 years. Both Ethiopia and Somalia signed a peace treaty in 1988. The border dispute with Eritrea, however, was a matter of great concern. In 1993, Eritrea established formal independence from Ethiopia. Border dispute during 1998 took the shape of war in 1999. Both the nations signed a peace treaty, but tensions were still persistent. (Neil desai 2015) Amidst lots of animosity between the two countries happened a change of political regime in Ethiopia in 2018. The first step the new regime took was to reconcile with its northern enemy Eritrea after two decades by ending the cold war. (The Economic Times 2018)

Ethiopia has opted for proper structures planning of its goals towards development since more than five decades now. During the 1950s, different plans and programs were prepared without any generalized structure to them for sectors like industry, agriculture, education, transport, forestry, and water management. Eventually, the structured multi-sectoral development took place after the establishment of the National Economic Council in 1955 to plan and formulate future goals. (Tesfaye Asfaw 1995) This policy-making group was chaired by the emperor 'Haile Selassie' himself. The objective of this agency was to create plans for improving agricultural and industrial activities, reduce poverty and illiteracy levels, provide improved healthcare, and obtain better standards of living.

The National Economic Council prepared its first 5-year plan for the period of 1957 -1961 focusing on the construction, transportation, and communication sectors. The second 5-year plan highlighted on the manufacturing sector, modernization, spreading of economic activities. The third 5-year plan also supported the objective of its predecessor to facilitate well-being in the country as well as to promote the educational opportunities (The Library of Congress 1998) These developments led to the establishment of the planning commission in the country.

Table T2: Ethiopia's Total Primary Energy Supply Data, Source: (IEA 2018a)

Total Primary Energy Supply (TPES) by source - Ethiopia							
Units: ktoe							
Year	Coal	Natural ga	Nuclear	Hydro	Geotherm	Biofuels ar	Primary and secondary oil
1990	0	0	0	91	0	22010	814
1995	0	0	0	123	0	26232	912
2000	0	0	0	142	4	30455	1086
2005	0	0	0	244	0	35119	1509
2010	31	0	0	424	15	40242	1922
2015	253	0	0	832	65	45872	3042

	Coal*	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geothermal, solar, etc.	Biofuels and waste	Electricity	Heat	Total**
	ktoe	*ktoe*	*ktoe*	*ktoe*	*ktoe*	*ktoe*	*ktoe*	*ktoe*	*ktoe*	*ktoe*	*ktoe*
Production	0	0	0	0	0	895	70	47 048	0	0	48 013
Imports	272	0	3 729	0	0	0	0	0	0	0	4 001
Exports	0	0	0	0	0	0	0	0	-15	0	-15
International marine bunkers***	0	0	0	0	0	0	0	0	0	0	0
International aviation bunkers****	0	0	-471	0	0	0	0	0	0	0	-471
Stock changes	0	0	7	0	0	0	0	0	0	0	7
TPES	272	0	3 265	0	0	895	70	47 048	-15	0	51 535
Transfers	0	0	0	0	0	0	0	0	0	0	0
Statistical differences	0	0	-19	0	0	0	0	0	0	0	-19
Electricity plants	0	0	-1	0	0	-895	-70	0	965	0	-1
CHP plants	0	0	0	0	0	0	0	0	0	0	0
Heat plants	0	0	0	0	0	0	0	0	0	0	0
Gas works	0	0	0	0	0	0	0	0	0	0	0
Oil refineries	0	0	0	0	0	0	0	0	0	0	0
Coal transformation	0	0	0	0	0	0	0	0	0	0	0
Liquefication plants	0	0	0	0	0	0	0	0	0	0	0
Other transformation	0	0	0	0	0	0	0	-9 174	0	0	-9 174
Energy industry own use	0	0	0	0	0	0	0	0	-29	0	-29
Losses	0	0	0	0	0	0	0	0	-164	0	-164
Total final consumption	272	0	3 245	0	0	0	0	37 874	757	0	42 148
Industry	272	0	792	0	0	0	0	0	261	0	1 326
Transport	0	0	1 734	0	0	0	0	6	0	0	1 741
Other	0	0	626	0	0	0	0	37 867	496	0	38 989
Residential	0	0	289	0	0	0	0	37 490	284	0	38 064
Commercial and public services	0	0	59	0	0	0	0	377	206	0	642
Agriculture / forestry	0	0	139	0	0	0	0	0	0	0	139
Fishing	0	0	0	0	0	0	0	0	0	0	0
Non-specified	0	0	139	0	0	0	0	0	6	0	144
Non-energy use	0	0	93	0	0	0	0	0	0	0	93
-of which chemical/petrochemical	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

Table T3: Ethiopia's total energy statistics, Source: (AFREC 2015)

Category	2000	2005	2010	2015 P
Production of coking coal	0	0	0	12
Production of charcoal	686	778	3 530	4 394
Production of crude oil, NLG and additives	0	0	5	0
Production of natural gas	-	-	-	-
Production of electricity from biofuels and waste	0	0	0	26
Production of electricity from fossil fuels	2	4	3	48
Production of nuclear electricity	-	-	-	-
Production of hydro electricity	154	245	420	1413
Production of geothermal electricity	0	0	2	47
Production of electricity from solar, wind, Etc.	0	0	0	173
Total production of electricity	156	249	424	1 708
Refinery output of oil products	-	-	-	-
Final Consumption of coking coal	0	0	26	184
Final consumption of oil	1,099	1,692	1,911	2,249
Final consumption of natural gas	-	-	-	-
Final consumption of electricity	121	207	385	654
Consumption of oil in industry	294	411	587	804
Consumption of natural gas in industry	0	0	0	0
Consumption of electricity in industry	47	85	120	149
Consumption of coking coal in industry	0	0	26	184
Consumption of oil in transport	642	1 050	1,333	997
Consumption of electricity in transport	0	0	0	0
Net imports of coking coal	0	0	13	168
Net imports of crude oil, NGL, Etc.	0	0	0	0
Net imports of oil product	1,064	1,518	2,313	2,563
Net imports of natural gas	-	-	-	-
Net imports of electricity	0	0	0	-34

(AFREC, 2015)

- : Data not applicable
0 : Data not available
(P): Projected

Declaration in lieu of oath

By

Deepak Kumar Mohapatra

This is to confirm my master’s thesis was independently composed/authored by myself, using solely the referred sources and support.

I additionally assert that this thesis has not been part of another examination process.

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Place and Date *Signature*