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The Drive towards Development of Hydropower Dominated Energy Source and Its Socio-Economic and Environmental Implications in Ethiopia

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Abstract
Ethiopia is currently driving towards development of hydropower dominated energy source in order to meet the energy demand of its economic sectors. However, the domination of this modern source of energy is expected to be realized if it can substitute the currently dominant modern source of energy, i.e. imported fossil fuel. Besides, hydropower generation is said to have adverse socio-economic and environmental impacts. In cognizant of this, this term paper was prepared: to explore the pros and cons of hydropower generation and to investigate substitutability of this source of energy with fossil fuel. The paper was prepared using extensive review of literatures as well as quantitative regression analysis using time series data having 39 years of observation (from 1971 – 2009). Result of the review of literatures reveals that multiple benefits can be derived from hydropower generation; which may also accompany with various socio-economic and environmental risks. On the other hand, the quantitative regression analysis shows that, even if there is negative association between hydropower generation and the proportion of energy derived from imported fossil fuel, increase in hydropower generation overtime could not significantly reduce the proportion of energy derived from the fossil fuel, yet, due to the country's huge demand for energy. Hence, it is recommended that huge expansion of hydropower generation is required for hydropower to be the dominant energy source, provided that hydropower can fit to the energy demand of most of the sectors. Moreover, sustainability of development of the economy relying on hydropower dominated energy source is expected to be realized only if the possible risks and costs are appropriately managed.
Keywords: Hydropower generation, benefits, risks, fossil fuel, substitutability

1. Introduction

Ethiopia is currently considered among those developing countries in which higher rate of economic growth is being registered. The country is at a critical crossroads with a burgeoning population, a depressed national economy, insufficient agricultural production, and a minimal number of developed energy sources. Hence, the Ethiopian government, in realization of the productivity enhancing effect of infrastructure, has pursued an ambitious infrastructure expansion program for the past fifteen years. In the past five years, power sector development has taken off with several large power projects going into construction (Block and Strzepek, 2010). Electricity is considered to be a critical economic infrastructure for such fast growing economy. If not delivered where and when needed, serious damage ensues for the economy. Considerable potential output has been lost due to power cuts in the past few years. Potential losses from power disruption will increase in the future as the economy grows and the relative contributions of the industry and service sectors increase in the economy. Thus, power supply must increase as rapidly as demand to ensure sustained growth. This is the rationale upon which the government is accelerating its investment in expanding the power system (ERG, 2009).

Potentially, Ethiopia is endowed with vast energy resources. The gross hydropower potential of the country is estimated at 650 TWh per year of which 25 per cent could be exploited for power. Over 70 billion m^3 of natural gas, more than 1,000 MW of geothermal power, and several hundred millions of tons of coal and oil shale constitute the energy potential so far estimated (FDRE – MWR, 2002).

Actually, traditional energy resources such as fuel wood and animal residue (biomass) are estimated to generate about 92% per cent of the energy consumed. Electricity and imported oil products supply the remaining 8 per cent (with 2% and 6%, respectively) (JICA, 2012). The electricity supply is generated domestically, with hydroelectricity accounting for over 90 per cent of supply. Oil is imported in the form of refined products (FDRE – MWR, 2002).

This indicates that energy supply and consumption in Ethiopia is highly dominated by traditional (biomass) sources. However, bio-energy uses in Ethiopia are generally not sustainable: according to a recent study, in more than two-thirds of districts bio-energy uses surpass sustainable yields. Bio-energy contributes to greenhouse gas emissions, due to deforestation and non-renewable use of biomass; in addition to other local environmental problems it creates (Hilawe et al, 2011). As the result, the national energy policy shifts towards modern energy sources (JICA, 2012).

On the other hand, for the modern energy sources, use of fossil fuels (petroleum) takes the largest share of supply/consumption. As indicated in FDRE – MWE (2002), survey by the Central Statistics Agency (CSA) in 2004 showed that about 71.1% of the total households use kerosene for lighting followed by firewood (15.7%) and electricity (12.9%). However, the import of petroleum products is stated to be a major fiscal strain for the government and major drain on export earnings. The problem of reliance on imported fossil fuel is exacerbated due to continuous world oil price hike (Hashim, 2007).

Moreover, the use of this energy source is reported to be among the causes of carbon dioxide emission and climate change. According to the report of Anonymous (2011), the main sources of emission from the energy sector are the residential, transport and manufacturing sub-sectors. Greenhouse gas emissions from the energy sector are due to carbon dioxide released during combustion of fossil fuels and methane released from the combustion of fuel wood and the production of charcoal.

Therefore, hydropower is believed to be the most economically viable power generation resource for Ethiopia; but only five per cent of the available potential is now utilized. The government has now made considerable commitment to accelerate the development of hydropower resources with the view to increase output to 40GW (or about a quarter of the total potential available) by 2015 to 2020 (Hilawe et al, 2011).

Access to public electricity supply, in terms of percentage of population with access to a low-voltage supply, has been growing steadily but slowly. The rate of electrification must stay ahead of the population growth rate in order to register any growth in access to electricity. That has not been easy in a country whose population grows at about 3 per cent annually. According to ERG (2009), system capacity is planned to quadruple before 2015. The midterm expansion plan to 2015 contains mainly hydropower plants thus increasing the hydropower share to nearly 100%.

The question that may be raised with regard to the plan of having a hydropower dominated modern source of energy is that whether hydropower generation can substitute fuel (i.e. imported) energy. The problem is that some sectors may be by their nature of installation demand fuel than electric power. In addition, there are a number of risks associated with high specialization in hydropower generation, which are related to the vulnerability of the power system to natural hazards and in its social and environmental impacts.

Moreover, according to ERG (2009), development of power infrastructure is capital intensive and thus difficult to finance in capital poor countries such as Ethiopia. These factors point to the need for sound strategies and planning for the power sector. Shortcoming in good strategies and plans will result in inadequate supply or costly over investment. Both reduce benefits: under investment curbs economic expansion, over investment ties resources that could be invested elsewhere. While good strategies and plans are essential in all countries they are critical in developing countries because of their limited access to power which constrains their growth, scarce capital, and fragile social and environment conditions.

In this regard, Commerford (2011) states;

"On today's news, one cannot escape the various reports and commentary concerning energy demands and the rising costs of electricity. Especially now in the aftermath of the 2011 nuclear disaster in Japan, the question as to how to produce cheap electricity if we forego nuclear power plants looms large. The industrialized world has become extremely dependent on electricity and expects and demands supply at reasonable prices. Why can supply not meet demand anymore? First, the world's population is exponentially increasing. Secondly, the demand for energy is constantly increasing in less developed or developing countries. Thirdly, the scarcity of fossil fuels is fundamentally responsible for the increased costs. With these three concerns in mind, hydroelectricity is a very tempting alternative especially given easy use and apparent lack of carbon dioxide emissions. However, when the total environmental and social impacts are included, hydroelectricity might not be an appropriate solution to meet the world's future energy needs".

In consideration of the existence of these pros and cons of power generation, this paper intends to figure out and evaluate;

i) The possible benefits derived from hydropower generation in the context of Ethiopia.
ii) The extent to which the hydropower generation substitutes imported liquid fuel, overtime.
iii) The possible risks/costs associated with the hydropower generation.

This paper was organized in such a way that the first and the last parts are prepared based on review of previously undertaken literatures. The second part deals with own time series analysis of substitutability of imported liquid fuel with the increase in hydro power generation. This was undertaken using a time series data extracted from Ethiopian Economics Association – Ethiopian Economic Policy Research Institute (EEA – EEPRI) 2012 data base.

2. Benefits of Hydropower Generation

According to the report of ERG (2009), Ethiopia has 30 to 45GW of hydropower potential. Hydropower is the largest known domestic source for power generation in the country. As stated in different publications, the main benefits of hydropower in the Ethiopian context are mentioned as follows:

i) Meeting power demand of the country cheaply

At the present time in Ethiopia, hydropower is financially considerably cheaper than alternatives.

Ethiopia is at an early stage of hydropower development and there are still a number of low-cost hydropower plants for future development. On purely economic ground hydropower is currently the least cost generation option for Ethiopia which can also enhance rural electrification. As an indigenous resource hydropower enhances security of energy supply. As a poor country with limited hard currency earning, Ethiopia must shield itself from high dependence on imports (and price shocks for imports) for critical services including power. Specialization in hydropower enhances capacity to develop similar projects in the future and lowers total costs. If properly planned and executed an accelerated development of hydropower in the country should enhance local capacity to build, manage, and operate hydropower plants thus lowering overall costs and increasing reliability (ERG, 2009).

ii) Mitigation of land degradation and soil erosion

Hydropower generation is expected to reverse the alarming land degradation and soil erosion, often caused by deforestation in the search for fuel and for charcoal production. The country is expected to be unable to stop poor and desperate households from cutting trees without providing an alternative-in other words an affordable cheap energy supply (Anonymous, n.d.).

iii) Avoidance of CO_2 emission

Environmental and social impact assessment of the Gibe III Hydroelectric Power Project mentions that hydropower offsets thermal or other types of generation. Besides replacing capacity and energy, the use of hydropower also leads to a reduction of thermal plant emission (Anonymous, n.d.).

iv) Promotion of gender equality

Hydropower generation is also critical to ease the literally backbreaking burden on women and promote gender equality. This is because it is the women in rural areas who bear the burden of travelling tens of kilometers to collect firewood daily (Anonymous, n.d.). Environmental and social impact assessment of the Gibe III Hydroelectric Power Project states that women as well as men will benefit equally from the employment opportunities that will be created and from convenient and safe access road facility. Women often run shops and bars in the area and during the construction period, it is anticipated that there will be further income generating activities for women such as food catering/restaurants for workers on the construction sites, more bars, and the selling of local products to construction camp workers. These activities will benefit mainly women who are very often the sole supporters of their families (EEPCO, 2008).

v) Enabling navigation on the river, tourism and recreational facilities

Water from reservoir of a hydropower project dam can be used to develop public recreational facilities like water parks for water sports and gardens (ECA, 2012). It is also expected to enable navigation on the river. The Gibe III Hydroelectric Power Project's reservoir is said to offer potential for eco-tourism, environmental education, etc. for bird watching and sport fishing (EEPCO, 2008).

vi) *Job opportunities and improve local livelihoods*

On the wider level, hydropower projects will create numerous job opportunities and improve local livelihoods. Clean and renewable energy at cheaper prices will also be available to the people. Projects of broadly similar type and magnitude to Gibe III are expected to comprise total workforce of more than 5000 persons at peak time on construction contract. The production of more hydropower would also allow the expansion of power-requiring industries and factories in the surrounding urban areas creating more permanent job opportunities for the displaced and other people in the area (EEPCO, 2008).

vii) Fisheries development

The reservoir of hydropower dams can also be used for fishery activities. For instance, the Gibe III hydropower project is expected to create a reservoir of 20,000 ha in area and 240 meter deep at the dam site. This is a large artificial lake that provides different environmental and ecological niches for diverse fish species, requiring habitats with varying depth from shallow littoral zone to deep demersal and pelagic areas. The reservoir fishery is much more productive than the riverine fishery (which is not utilized at the moment). This may directly occupy more than 300 families on a long term basis. Thus, it could be taken as an opportunity in terms of developing a more productive and flourishing fishery that helps to improve source of income in the area and to obtain additional benefit for the local fishermen (ibid).

viii) water conservation

This is the case related to projects like the Great Ethiopian Renascence Hydropower Dam Project (GERHDP). According to a report on GERHDP, the GERHDP will minimize the evaporation loss from dams located in less favorable downstream desert settings. A total of close to 19 billion cubic meters (BCM) of water evaporates from the Aswan High Dam and other dams in Sudan (of this evaporation from Aswan alone amounts to 14.3

BCM) annually. Evaporation at the Jebel Aulia dam in Sudan amounts to 3.5 BCM annually from 1.75 BCM storage capacity. By contrast evaporation loss from the full development of the GERHDP is likely to be no more than 0.4 BCM (Anonymous, n.d.).

The report also mentions that, in fact, the development of GERHDP will encourage the decommissioning of wasteful dams like Jebel Aulia and reduce the operating level of the Aswan High Dam, and other dams in Sudan. The result will be saving of over 6 BCM of water for the Nile system annually. Another plus will be in sediment management. Most of the dams in Sudan are suffering from silting with the effect they have lost over 50% of their live storage capacities. Downstream hydraulic infrastructures, especially when complemented by integrated watershed management, would benefit from the construction of the GERHDP. The amount of sediment reaching dams and water conveyance structures in Sudan and Egypt will start to be reduced as soon as the first impoundment starts.

ix) drought and flood management

Hydropower projects are said to have a major impact on mitigation of drought and on flood management. A number of important studies indicated that semi-arid and arid countries to be more affected by climate change than temperate countries. As mentioned in Anonymous, (n.d.), a recent study commissioned by the Eastern Nile Technical Regional Office, for example, concluded that water infrastructure development, including reservoir construction was one of the five pillars identified to adapt or mitigate extreme hydrological events, including the alteration of droughts and flooding, most likely to be caused by climate change.

The assessment report on Gibe III project states the reservoir will provide flood protection (reduce floods both in peak and in frequency) to downstream areas. As a result, the damage due to floods like loss of crops, dwellings and the suffering and possibly death of affected people will reduce. The measurements carried out that occurred in August 2006 indicated a peak flood flow in the range of about 3,500-4,000 m^3/sec, being a quite frequent flood with a return period of less than 10 years. With this regulation, areas prone to frequent flooding can be used for agricultural purposes (EEPCO, 2008).

x) Irrigation schemes

Large hydropower projects are usually multi-purpose projects with potential for irrigation and water regulation (flood control, regulated releases during dry periods). Large multi-purpose hydro projects can increase irrigated agriculture. As indicated in the report of EEPCO (2008), according to the expectations of the weredas' officials, with the construction of the dam and creation of the reservoir, the Omo River will come closer to the nearby settlements and the people will have the opportunity to use the river water for small scale irrigation development. The expansion of irrigation farms would increase crop production per unit area and contributes to higher income and increased food security to the community.

xi) Reduction of fiscal restrain

Hydropower can be an export industry that will bring substantial income to the country. For instance, EEPCO expects to generate US$450 million annually from power export from the Gilgel Gibe 3 plant (this, of course, depends on the actual amount exported and the tariff that will be acceptable to the importers). If this plan is realized it will augment export income by 30% and will increase available resources for development. Moreover, since hydropower export will likely displace thermal power in the importing countries (Sudan, Kenya, and Djibouti) rising petroleum prices could mean rising hydropower prices. Therefore, hydropower can shield Ethiopia from petroleum price volatility (ERG, 2009).

3. Substitutability of Imported Fuel with Hydropower Generation

As it was explained in the preceding parts, Ethiopia has a plan to expand its modern sources of enery. Currently, the mostly used energy sources are hydropower energy and imported fossil fuel. However, the use of the imported fossil fuel is expected to have significant adverse economic and environmental effects than that of hydro power generation.

According to the report of National Bank of Ethiopia, as indicated in the data base of EEA/EEPRI (2012), the country spent 22,299,900,000 birrs in 2010/11 to import petroleum which is the largest expenditure constituting about more than 17% of the total expenditure on imports. This amount of expenditure on imported petroleum is more than 15% of the country's GDP. This clearly shows how the country is facing higher rate of fiscal strain as the result of petroleum consumption. The hydropower generation is expected to reduce such fiscal strain if it can substitute the imported fuel consumption.

In addition to such adverse economic implication, petroleum consumption is also said to be the major factor leading to higher rate of carbon dioxide emission damaging the environment. Estimations stated in the aforementioned data set show that the proportion of carbon dioxide emission from fossil fuel is more than 87% of the total emission, in 2008. In the same period, the proportion of carbon dioxide emission from electricity and heat production was estimated to be only about 6.6%. This reveals that hydropower generation is much better than that of fossil fuel in terms of environmental damage.

Hence, given the stated benefits that can be derived from the hydropower generation, the country is driving towards having hydropower dominated energy source. However, this can only be realized provided that the hydropower source can substitute the imported fuel energy. In other words, those sectors which are relying on fuel energy should alternatively use hydropower.

For decades, the government is expanding the hydropower energy source. Hence, the question is whether the expansion in the hydropower generation has actually reduced the proportion of energy derived from fossil fuels; and whether it will reduce this proportion in the future as well. In cognizant of this, in this part, this study deals with the extent to which the expansion of the hydropower generation intends to reduce the proportion of consumption of energy from imported fuels, and the implication for the future.

This analysis was carried out using time series data extracted from Ethiopian Economics Assoction – Ethiopian Economic Policy Research Institute (EEA – EEPRI) data base, for the period from 1971 until 2009; with observation of 39 years. The major variables considered in this analysis include: amount of hydropower generation (in KWH), proportion of consumption of energy from imported fossil fuels, and real Gross Domestic Product (GDP) of the country.

The real GDP of the country was considered to incorporate the effect of change in demand for energy on imported fuel. In order to show the correct relationship between the amount of hydropower generation and the proportion of energy derived from imported fuel, it is important to consider the effect of other variables (eg. Increase in demand for energy); that is the rationale behind considering real GDP in the estimation of the regression. Other variables such as level of population of the country and output of the manufacturing sector had also been considered initially; but dropped due to existence of multicollinearity in the estimation.
The data was analyzed using the following steps/procedures.

i) Test of stationarity (unit root test) for each variable using Augmented Dickey Fuller test
ii) Test of integration among the variables using Johansen's approach
iii) Analysis of linear regression using logarithm

a) Test of stationarity (unit root test) of each variable[1]

In a time series analysis, it is necessary for the univariate characteristics of the data to be analyzed to avoid the problem of spurious regression. This study uses the Augmented Dickey-Fuller (ADF) test to analyze the long-run stationarity of the variables. The results of the ADF test inform the type of estimation technique to be used. Estimation result of the unit root test is indicated in table 1.

Table 1: Test of unit root for each variable using ADF

Series	Included number of lags	Computed values		Critical values			Stationarity order
		Level	1st deference	1%	5%	10%	
fuencoper	1	-.3554729	0.0338717	-4.270	-3.552	-3.211	I(0)
hpg	1	-0.1581387	0.5799539	-4.288	-3.560	-3.216	I(1)
gdp	1	0.1322717	0.2023229	-4.270	-3.552	-3.211	I(0)

Source: own computation, 2014

The unit root test reveals that the data for amount of hydropower generation is not stationary in level. The ADF test provides evidence for the existence of a unit root in this data series. On the other hand, the other variables were found to be stationary in levels. Hence, since at least one of the variables is non-stationary in level, it is necessary to test for the existence of cointegration. If the series are co-integrated, that means there is a long-run relationship between them.

b) Test of Co-Integration among the Variables

This analysis followed the Johansen's approach of testing for co-integration. Table 2 shows result of the Johansen's test of co-integration. The table shows that for the rank, r = 0, both the Trace and Max statistics are greater than their respective 5% critical values. Hence, we reject the null that there is no co-integration among the variables. For rank of r = 1, both the Trace and the Max statistics are less than their respective 5% critical values. Thus, we accept the null that there is no more than one way of co-integration. This result implies there is long-run co-integration among the variables. Hence, this co-integration possibly be included in our linear regression model.

[1] Before the test of the unit root, the number of lags to be include for each variable were identified using *LR, FPE,* AIC, HQIC and SBIC statistics of information criteria (appendix 1, appendix 2 and appendix 3)

Table 2: Result of Johansen's tests for co-integration among the variables[1]

Rank	Eigen value	Trace		Max	
		statistics	5% critical value	statistics	5% critical value
r = 0	------	56.1348	34.55	39.1024	23.78
r ≤ 1	0.64264	17.0324*	18.17	12.4266*	16.87
Number of obs = 38 Lags = 1					

Source: own computation, 2014

c) *Analysis of the Linear Regression*

The linear regression was estimated in order to show the effect of expansion of hydropower generation on the proportion of energy (from the total energy) consumed using imported fuel. As indicated earlier, in order to control the effect of other variables (change in demand for energy) on the extent of the use of imported fuel, real GDP of the country was considered in the estimation. Besides, the regression was estimated using logarithmic form taking logarithm of the proportion of energy consumed from imported fuel [i.e. Log (fuencoper)] as a dependent variable whereas logarithm of amount of hydropower generation [i.e. Log(hpg)] and logarithm of the level of real GDP [i.e. Log(gdp)] were considered as independent variables. The functional specification is stated as shown below. Such functional specification is advantageous in that it is able to explicitly control the effect of various variables on the dependent variable (Deschenes and Greenstone, 2004).

$\text{Log}(fuencoper_t) + \beta_0 + \beta_1 \text{Log}(hpg_t) + \beta_2 \text{Log}(gdp_t) + \varepsilon_t$ ………………………….. (1)

Where: fuencoper is fuel consumption as a percentage of total energy consumed at time t
hpg_t is amount of hydropower generation in KWH at time t
gdp_t is level of real GDP of the country at time t
β_0, β_1 and β_2 are parameters estimated
ε_t is error term at time t

Note: While estimating this regression, other variables which are expected to affect the dependent variable were dropped due to problem of multicollinearity. The estimation was made using robust regression in order to coup-up with minor problems normality, hetroskedasticity, and autocorrelation. Test of problem of multicollinearity and stability (volatility) of the estimation result were reported in appendix 5 and appendix 6, respectively. The model was found to be free from problem of multicollinearity and instability.

Table 3: Linear regression result
Dependent variable: Log (fuencoper)

Variable	Coefficient	Robust Standard Error	T-statistics	P-value
Log(hpg)	-0.043724	0.1047018	-0.42	0.679
Log(gdp)	0.5272497	0.1995408	2.64	0.012
_cons	-10.42762	2.960448	-3.52	0.001
Number of observations = 39 F(2, 36) = 22.65 Prob > F = 0.0000 R-squared = 0.6246				

Source: Own computation, 2014

Result of our regression estimation was reported in table 3. The table shows that R-squared = 0.6246 implying that more than 60% of the variation in the outcome is explained by our model; and the Prob > F = 0.0000 indicates that the regressors in our model are jointly significant to affect the dependent variable. Given this, result of our estimation reveals that there seems to be opposite relationship between the proportion of energy consumed using imported fuel and hydropower generation; but this relationship was found to be insignificant even at 10% level of significance. As indicated in the table, coefficient of log (hpg) is negative (i.e. -0.043724), but the P-value for this coefficient is 0.679 revealing there is no relationship between the two variables.

[1] Before the Johansen's co-integration test was carried out, number of lags to be included for the estimation was identified using *LR, FPE,* AIC, HQIC and SBIC statistics of information criteria (appendix 4).

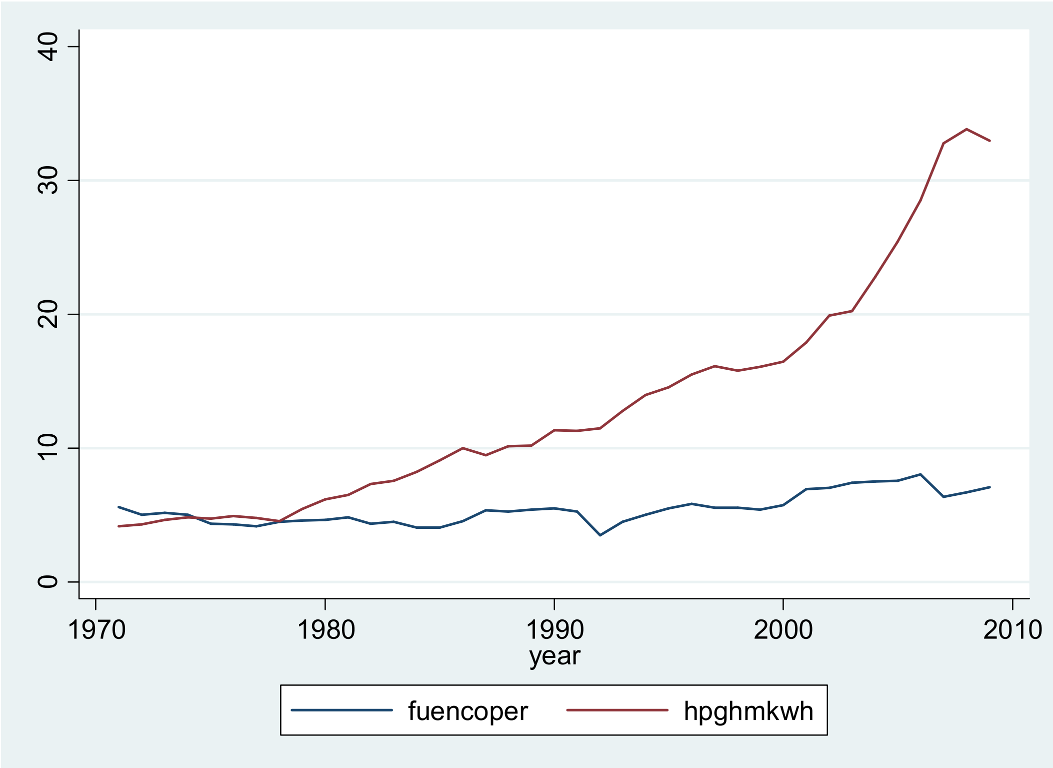

Figure 1: Trends of the amount of hydropower generation (in 100 million kwh) and the proportion of energy generated from imported fuel, overtime

In order to show the effect of the amount of hydropower generation on the proportion of energy consumed using imported fuel, graphical presentation (time series two way line) was also used, as shown be figure 1. The figure shows that there is continuous rise in the amount of hydropower generation overtime. However, we can see that there seems to be no change in the proportion of energy consumed using imported fuel. This may be one way to confirm that the rise in the amount of hydropower generation does not have significant effect of the proportion energy consumed using imported fuel.

The major reason for the insignificance of the effect of the rise of the amount of hydropower generation on the proportion of energy consumed from the use of imported fossil fuel may be the continuous rise in demand for energy in the country, as the country's output is increasing overtime. This is revealed by the regression result shown in table 3. The table shows that coefficient of logarithm of real GDP (i.e. loggdp) and its P-value are 0.5272497 and 0.012. The implication is that as the country's real GDP is increasing, the demand for imported fuel increases to the extent that there is a rise in the proportion of energy consumed from imported fuel.

In fact, it is obvious that the country's demand for energy is increasing overtime; in contrast, it is observed that there are a lot of power disruptions in the country. Moreover, there are many sectors which are, by their very nature of installation, characterized by using only imported fuel than hydropower. All these factors are expected to have significant effect over alteration of the substitutability of imported fuel with hydropower generation. However, we may expect that if the country is able to meet the energy demand through huge development of the hydropower generation in the future, the proportion of energy derived from imported fossil fuel reduces with the expansion of the hydropower generation.

4. Costs/Risks Associated with Hydropower Generation

Even if hydropower generation is an indigenous source of energy for Ethiopia and expected to have multidimensional benefits for the country, it is associated with a number of costs and risks. The risks/costs of a hydro dominated power system development strategy for Ethiopia may be divided in two: the first is the risk to the power system itself due to its almost exclusive dependence on a single resource; the second is the social and environmental impacts of an accelerated hydropower development (ERG, 2009).

a) Vulnerability of a hydro dominated power system

Near exclusive dependence on a single type of resource for a critical application, such as power, exposes a country to significant risks. As dependence on the particular resource deepens, vulnerability rises because the impact of the consequences rises. Recent power cuts cost the Ethiopian economy 1% in GDP growth. Future power disruptions will cost more due to increased dependence of the economy on power (due shifts to manufacturing and services). Similar level of power outage as now will cost higher than 1% in GDP growth and much higher loss in output (ERG, 2009).

A hydro dominated strategy makes the power system and the economy vulnerable to climatic variations, geo-hazards, economics and politics. Ethiopia is highly prone to climatic variability; variability is increasing while at the same time there is gradual decline in rainfall. Some areas are vulnerable to geo-hazards and this poses problems for the stability of large hydraulic structures such as dams (ibid).

Hammond (2013), for example, states that water management on the Nile is complicated by its high variability; and climate change could compound these difficulties. There is significant uncertainty over its impact on flows in the Nile, although a recent study has shown observed and projected decreases in runoff in the Blue Nile as a result of reduced rainfall. Ethiopia's heavy reliance on hydropower may be a risky strategy. Ethiopia also lacks water storage facilities, and as a result has been described as "hostage to its hydrology". In a study by the World Bank, the cost of hydrological variability has been estimated at over a third of its annual GDP, yet it has only 1% of the reservoir storage capacity of North America to manage this variability. The World Bank has argued that increased investment in multipurpose water infrastructure would make Ethiopia more "water-resilient", and promote long-term economic growth.

According to Habtom (2009), on his study conducted on Upper Nile Basin (Gilgel Aabay) reservoir, projection of the evaporation from the open water generally shows an increasing trend i.e. it exhibits an average annual increase of about 20 % at the end of the next century. This causes its own impact on the reservoir water balance by changing the reservoir volume. His study projects that the average annual inflow volume will decrease by 2%, 3% and 2.3% in 2020s, 2050s and 2080s respectively. However, the study concluded that the Gilgel Abay reservoir has high capability to meet the required target demand in the next century.

In addition to the effect of climate change, a degraded local environment (vegetation and soils) increases the cost of hydraulic structures and reduces their useful life. Vegetation loss and consequent soil erosion means that dams silt up much faster; they provide less than planned output while in operation and their useful life is cut short. Erosion and landslides make it costly to build and maintain civil structures. The flood control benefits of dams are quickly lost when dams silt up (ERG, 2009).

Ethiopia is highly prone to soil erosion as close to 80% of the land has 15% or higher slope (WB, 2006). This coupled with massive deforestation results in heavy rains washing away soils. The storage capacity of dams is lost rapidly in some cases while still under construction (WB, 2006):
In the city of Gonder, for example, during construction alone, 20–30 percent of the projected volume of the new water system's capacity was lost due to siltation caused by deforestation upstream in the Angereb River. An additional five wells and a pipeline had to be constructed at a cost of approximately Br 5 million to augment the town's water supply during the rainy season (ERG, 2009). Sediment accumulation in intakes and outlets hamper proper operation of dams and reduce availability of hydropower dams. Sedimentation also causes reservoirs to submerge more area with consequent losses in land use, biodiversity, and social impacts (Bezuayehu. 2006).

Moreover, ERG (2009) states that hydropower generation may also be vulnerable to geo-hazards. Hydropower dams and reservoirs are major physical infrastructure. Their failure seriously impacts life, livelihoods and the economy at large. Areas of Ethiopia in and adjacent to the Rift Valley are reported to be prone to seismic activity. For instance, several earthquakes are recorded for the Gibe area in the past hundred years (EEPCO, 2008). Structures are designed to withstand seismic activity. However, the scale and frequency of the activities cannot be predicted. Greater dependence on large hydro structures exposes the power system to higher risks. Other geo-hazards associated with large hydropower plants include land slides (reservoir banks), erosion, and seepage that may compromise availability and output.

b) Environmental and social impacts of hydropower generation

Hydropower projects involve the development of multiple large scale civil works including roads, dams, water conveyance, housing and other structures. Development of these structures creates significant environmental and social impacts while under construction and long after completion. Impacts are not limited to project implementation areas since there are often leakage effects, as for example, displaced people move to other areas where competition for resources can arise. One critical aspect of large development projects such as hydropower is that the costs and benefits do not accrue to the same group of people. The losses are borne by local communities (often much poorer and vulnerable than the beneficiaries) while benefits go to relatively better off citizens (ERG, 2009).

For example, as Abeyu (2007) points out, although Tis Abay hydropower station is located near the villages, the majority of the residents do not have access to the electricity; only 27.9% of the surrounding residents in the towns have access to electricity the rest 72.1% use kerosene lamp and fuel wood as a source of light and for cooking. Therefore, the villagers continue to denude the remaining shrubs and trees for their daily consumption. In contrast, majority of these people are facing lack of any information system about releasing of excess water from the weir; for this reason sometimes accidents occurred and they also fear the loss of their children and their cattle.

The environmental impacts of large hydropower plants extend throughout a river basin. Soils, water resources, biodiversity, vegetation, settlements, health, and cultural and natural heritage are affected. Hydropower reservoirs also contribute to climate change through decay of submerged vegetation (ERG, 2009).

Dams alter the natural flow of water courses; they also change the quality, quantity, temporal and spatial availability of water. Water quality is affected due to increased erosion due to dams themselves, deforestation for construction of dams and other civil structures, and due to deforestation and cropping of land by relocating farmers. Dams also change the quantity and availability of water thus disrupting long-established farming practices (ERG, 2009). A study conducted by Abeyu (2007), related to the construction of Chara Chara weir on Tiss Issat falls, shows that the amount of fall of the river has reduced after the construction of the dam; and the fall of the river was found to be below the minimum requirement to sustain environmental flow functions of the river as well as to maintain the visual amenity of the Falls. Although dams do protect downstream population from floods, they also limit seasonal floods (which local populations may have adopted for local use) and transport of nutrients thus disrupting traditional recession agriculture (Cernea, 2006).

Construction of civil structures for large hydropower plants also result in significant losses in forests and woodlands. Tree resources are lost during construction of civil structures, inundation of reservoirs and due to relocation of people and consequent deforestation for agriculture and other uses. Important and singular plant and animal species may also be lost (ERG, 2009). For example, before the construction of the Chara Chara weir, the people were used to collect wild edible plants (fruits) from the riparian vegetation such as *Syzygium guineanse* (Dokma) and *Mimusops kummel* (Eshee) and also sold it and obtained cash every season to improve their living. However the productivity of the riparian vegetation has declined significantly since the weir became operational. Consequently, this income source of the villagers has been interrupted (Abeyu, 2007).

The other environmental adverse effect of hydropower dam is related to its possible impact on health of the surrounding society. Large reservoirs often result in the introduction of water borne diseases such as malaria and bilharzias. If the construction of the dam, is not accompanied by social services such as potable water and health care, health impacts are exacerbated (ERG, 2009).

Besides the environmental impacts, large hydropower projects may disrupt local social organizations and can destroy local heritage. Hydroelectric dams require large quantities of water which greatly reduce the livable land for both humans and animals. These large reservoirs are required for each hydroelectric plant to meet the electrical generation demands. For example, the Merowe Dam in Sudan was built to supply the nearby city of Karima with electrical power (NASA). Once finished, its reservoir contains 12.5 km3 (3.0 cu mi), or about 20% of the Nile's annual flow. The reservoir lake is planned to extend 174 km (108 mi) upstream. The dam displaces so much water that many tribes in the area had to be relocated. As the result, an estimated 55,000 to 77,000 people had to be relocated once the dam was approved, and their sacred land and cultural landmarks were destroyed (Commerford, 2011). This raises ethical questions.

Relocation of households previously living in reservoir areas to new areas sometimes exacerbates land degradation as new settlements may be located in relatively less suited to crop or livestock production (such as steeper slopes and marginal areas). This is reported to have been the case for the Finchaa reservoir (Bezuayehu, 2006). Dislocated populations are exposed to impoverishment risks of landlessness, joblessness, homelessness, marginalization, food insecurity, increased morbidity and mortality, loss of access to common property services and social disarticulation. These people may also lose their long-established social networks and associations and this may cause them stress and trauma; local cultural heritage (ways of living, languages, customs) and heritage sites including remains of historical, religious and spiritual value for local people may be lost (Cernea, 2006).

5. Concluding Remarks

Even if Ethiopia is considered to be among the poorest countries of the world, yet, the rate of economic growth and development achieved by the country currently is being appreciated internationally. The country is currently said to have an ambitious plan of achieving higher rate of economic growth in order to join middle-income countries within few years. However, this objective is expected to be realized only if it is able to increase its annual output its different economic sectors substantially. Its ability to bring about such substantial rate of growth relies on different factors, of which, significant expansion of infrastructures (over head capital) is the major one. Expansion of source of energy is one of the major infrastructures required to bring about the desired rate of economic growth.

In this regard, the country is said to have various sources of energy including traditional and modern sources of energy. Currently, it is focusing to expand the modern sources of energy for the fact that traditional sources have social and environmental adverse effects. Of the modern sources of energy, hydropower generation and fossil fuel are the major ones. However, the country is giving much emphasis for expansion of the hydropower generation. This is because hydropower generation is an indigenous source of energy for the country existing with huge potential; on the other hand, energy consumption from imported fossil fuel was found to have adverse economic and environmental impacts.

Hence, sustainability of economic growth and development of the country in the future is expected to rely on effectiveness and efficiency of the hydropower generation. In cognizant of this, the paper was prepared to investigate the pros and cons of hydropower generation as well as to figure out effectiveness of the hydropower generation to substitute imported fossil fuel.

Review of various literatures indicates that there can be multiple socio-economic and environmental benefits derived from the hydropower generation. Given these benefits, the other important issue of investigation is to show whether hydropower generation can substitute imported fossil fuel. Results of the time series quantitative analysis indicate that there is slightly negative association between amount of hydropower generation and the proportion of imported fossil fuel consumption, with insignificant relationship. This may show that, at the current (early) level of development, the expansion in hydropower generation is not able to substitute the imported fossil fuel due to the limited amount of energy generated from hydropower source and the substantial need of energy by the country.

However, huge investment on hydropower generation may intend to reduce the proportion imported fuel consumption in the future, one the country's demand for energy reaches at saturation level, provided that the installation of some sectors (such as the transportation) can fit with hydropower energy source. For instance, the current investment of the country which is being made on electrically installed rail way transport and related activities are expected to reduce consumption of imported fossil fuel, given the amount hydropower generation is enough to fulfill the energy demand of the country.

The other important issue is that, given that the country is driving towards having hydropower dominated energy source, it has to consider the possible costs/risks associated with such type of source of energy. Review of the literatures also shows that there can be a number of risks which may accompany with hydropower dominated energy source; that may adversely affect sustainability of the development of the country and the energy source itself. Therefore, critical and appropriate measures have to be made, before hand, along with expansion of the hydropower generation.

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Appendices

Appendix 1: Determination of number of lags for proportion of energy derived from fuel consumption before test of unit root

```
. varsoc fuencoper

  Selection-order criteria
  Sample:  1975 - 2009                         Number of obs      =        35
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-55.1986				1.45279	3.21135	3.22669	3.25579
1	-30.001	50.395*	1	0.000	.364539*	1.82863*	1.85931*	1.91751*
2	-29.9867	.02864	1	0.866	.385776	1.88496	1.93098	2.01827
3	-29.9454	.08267	1	0.774	.407735	1.93974	2.0011	2.11749
4	-29.9347	.02135	1	0.884	.431866	1.99627	2.07297	2.21846

Appendix 2: Determination of number of lags for hydropower generation before test of unit root

```
. varsoc hpg

  Selection-order criteria
  Sample:  1975 - 2009                         Number of obs      =        35
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-768.371				7.3e+17	43.964	43.9794	44.0085
1	-692.5	151.74*	1	0.000	1.0e+16	39.6857	39.7164	39.7746*
2	-690.953	3.0941	1	0.079	9.8e+15*	39.6544*	39.7005*	39.7877
3	-690.405	1.0955	1	0.295	1.0e+16	39.6803	39.7416	39.858
4	-690.207	.39577	1	0.529	1.1e+16	39.7261	39.8028	39.9483

Appendix 3: Determination of number of lags for GDP before test of unit root

```
. varsoc gdp

  Selection-order criteria
  Sample:  1975 - 2009                         Number of obs      =        35
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-884.82				5.6e+20	50.6183	50.6336	50.6627
1	-811.618	146.4*	1	0.000	9.1e+18	46.4924	46.5231*	46.5813*
2	-811.084	1.0668	1	0.302	9.3e+18	46.5191	46.5651	46.6524
3	-809.377	3.4148	1	0.065	9.0e+18*	46.4787*	46.54	46.6564
4	-809.344	.06544	1	0.798	9.5e+18	46.534	46.6107	46.7561

Appendix 4: Determination of number of lags before the co-integration test among all the variables

```
. varsoc  fuencoper hpg gdp

   Selection-order criteria
   Sample:  1975 - 2009                              Number of obs      =        35
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1638.24				1.1e+37	93.7852	93.8312	93.9185
1	-1519.98	236.52	9	0.000	2.1e+34*	87.5418*	87.7259*	88.0751*
2	-1515.57	8.8158	9	0.454	2.8e+34	87.8042	88.1263	88.7374
3	-1508.43	14.297	9	0.112	3.2e+34	87.91	88.3702	89.2432
4	-1495.12	26.614*	9	0.002	2.6e+34	87.6639	88.2621	89.397

Appendix 5: Test of multicollinearity post estimation of the linear regression

```
. vif
```

Variable	VIF	1/VIF
loggdp	9.20	0.108754
loghpg	9.20	0.108754
Mean VIF	9.20	

Appendix 6: Test of volatility of the model using ARCH post estimation of the linear regression

```
. estat archlm
LM test for autoregressive conditional heteroskedasticity (ARCH)
```

lags(*p*)	chi2	df	Prob > chi2
1	0.308	1	0.5787

H0: no ARCH effects *vs.* H1: ARCH(*p*) disturbance