



Renewable energy technologies as beacon of cleaner production: a real options valuation analysis for Liberia



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ABSTRACT

The importance of energy consumption for growth and development calls for improved decision support for a sustainable energy transition. Given Africa's dependence on fossil fuels, the economic and environmental savings from research & development and deployment of renewable energy technologies may be substantial. Although the benefits of renewable energy technologies research & development funding may appear to be low assuming immediate deployment, the uncertainty in the non-renewable energy price and the flexibility over timing makes research & development program more appealing. This study develops different scenarios in order to quantify benefits provided by research & development funding for renewable power generation in Liberia by using real options pricing approach to estimate the value of renewable energy technologies while taking into account the uncertainty of fossil fuel prices and learning-by-doing in renewable energy technologies. The optimal solution shows that renewable energy technologies are economically attractive especially when external costs are internalized. However, annual research & development funding is low and should be raised significantly in order to guarantee the highest possible investment incentives with minimal expenditures. The study also hypothesizes that with the likelihood of renewable energy to replace non-renewable energy, renewable power use in Liberia can potentially reduce carbon dioxide emissions by approximately 13.9% by 2015 compared to the 2008 levels. The key insight provided by the real options analysis in this study is that, while renewable energy may have inherent limitations such as seasonality of supply, low energy content and capacity factor issues, they still hold a significant amount of value which can only be detected when externalities are internalized, thus underscoring the need for external costs-related policies.

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1. Introduction

Liberia has been recovering rapidly following decades of economic mismanagement and fourteen years of brutal civil war. The economy is resuscitating rapidly, with the government introducing a broad range of policies to foster peace, accelerate reconstruction and development, and build strong systems of governance. In formulating its development plans, the government of Liberia has recognized energy as a vital input to national development, accelerating reconstruction and economic revitalization, and the achievement of the millennium development goals (MDGs). Energy is an essential sector for Liberia because it cuts across all other

sectors and serves as a catalyst for social, economic and political growth and development. Furthermore there is a direct relationship between the country's overall development and its level of energy production, delivery and consumption (Wesseh and Zoumara, 2012; Wesseh and Lin, 2013; Lin and Wesseh, 2014).

Notwithstanding, carbon dioxide (CO₂) is responsible for 50–60% of the local greenhouse gas emissions into the atmosphere in Liberia. About 60% of these comes from the consumption of petroleum products, while the remaining 40% comes from traditional farming practices where woody biomass is burned during cultivation (NBSAPL, 2004). Therefore, large scale investment and financial flows to the energy sector specifically for the development of various renewable energy technologies (RETs) will be needed to reverse this trend (Costa-Júnior et al., 2013; Lin and Wesseh, 2013c, 2014a). Climate change mitigation (actions to minimize the

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Acronym used in the study

BR	Buchanan Renewables	LEC	Liberia Electricity Corporation
CO ₂	Carbon Dioxide	LPRC	Liberia Petroleum Refining Company
DCF	Discounted Cash Flow	LR _D	Learning Rate
ECOWAS	Economic Community of West African States	MDGs	Millennium Development Goals
FDA	Forestry Development Authority	MLME	Ministry of Lands, Mines and Energy
GBM	Geometric Brownian Motions	MW	Megawatts
gCO ₂	gram CO ₂	NEP	National Energy Policy
GDP	Gross Domestic Product	NOCAL	National Oil Company of Liberia
GHG	Greenhouse gas	NPV	Net Present Value
GWh	Gigawatt hour	NRE	Non-renewable Energy
IMPTC	Inter-Ministerial Petroleum Technical Committee	PR _D	Progress Ratios
KgCO ₂	Kilogram CO ₂	R&D	Research & Development
KWh	Kilowatt hour	RE	Renewable Energy
		RETs	Renewable Energy Technologies

magnitude and rate of long-term climate change) within the energy sector will require reduction in the consumption of fossil fuel, used primarily for the electricity generation and transport sectors (Zhai et al., 2014; Bhutto et al., 2014). The government must partner with actors in key economic sectors and relevant stakeholders to improve the efficiency with which energy is used and promote energy conservation measures, including support for the development of the carbon market nationally. Moreover, expanding the nation's supply of energy by encouraging renewable energy (RE) investment projects supports sustainable growth since RE source is inexhaustible. Developing the RE sector of Liberia will therefore present opportunities as the country could use its indigenous energy resources to generate electricity and meet other crucial energy needs. Although some kind of distribution network for biomass is still required in Liberia, one advantage of RETs is that they may be placed closer to where consumers are, thereby circumventing the need to site and build costly transmission lines. Furthermore, given that RETs rely on indigenous fuels as opposed to imported fossil fuels (Dovi et al., 2009), balance-of-payment problems and currency risks due to oil price instability may be greatly reduced. Significant domestic economic activities with multiplier effects (especially in rural areas) could also be generated as a result of embarking on RE projects.

Realizing these facts and in line with the international community's effort toward climate change mitigation and the commitment of sufficient energy access to all Liberians by carefully taking into account the environmental costs and benefits, the government of Liberia through the national energy policy (NEP) writes: "Cost is the main determinant of energy access and quality. It is therefore the policy of the government of Liberia (GOL) that the development and utilization of all forms of energy shall be done on a least-cost basis. Financial, economic, social, and environmental costs shall all be taken into consideration. The GOL supports the

collective global effort to control harmful greenhouse gas emissions responsible for climate change and will seek to balance the environmental costs and benefits of all energy programs. The GOL expects to achieve its access goals for 2015 while reducing greenhouse gas emissions by 10%, improving energy efficiency by 20%, raising the share of renewable energy to 30% of electricity production and 10% of overall energy consumption, and increasing the level of biofuels in transport fuel to 5%". Although strict policies on energy efficiency and conservation as well as fiscal and tax incentives for users of RETs have not yet been implemented, there have been efforts to scale up the use of RETs in the form of research and development (R&D) funding from the Liberian government in collaboration with its bilateral/multilateral donor institutions and end users finance. According to a United Nations development program (UNDP, 2011) report, the estimated average annual RETs R&D funding, although not consistent, stands at \$0.72 million/yr. Although one may argue that \$0.72 million/yr. is a rather small amount, as can be seen from Table 2, this study spans the period when Liberia's RE development goes from the emergency phase through the capacity building phase. During this time, R&D funding is expected to be at a minimum compared to the developmental stage which goes beyond the year 2015. Moreover, considering that total installed capacity of electricity generation in Liberia before the civil war was only 412 MW (MW), the average annual R&D funding for RE electricity generation appears to be a reasonable amount.

The goal of this study is to therefore investigate whether the current R&D funding level creates the requisite investment incentives necessary for achieving policy targets. Hence, the paper seeks to answer the following questions: (1) how can benefits derived from the R&D effort be valued or quantified? (2) Is the R&D funding level sufficient to stimulate private investment in renewable power generation? (3) If there is any consensus that the

Table 1
Share of Liberian energy consumption per source in 2008.

Category	Share (%)					
	Fossil	Hydro	Solar	Charcoal	Firewood	Candle Battery
Cooking and heating	0.5		84.5	15		
Lighting and others	55				37	8
Transportation	100					
Electricity production & industrial activities	90	9.7	0.3			

Source: Wesseh and Zoumara, 2012.

Table 2
Policies in place to promote RE since the Rio conference of 1992.

Year	Policy
2006	Emergency Power Program; Liberia Emergency Assistance Program
2007	Renewable Energy and Energy Efficiency Policy and Action Plan of Liberia
2008	Action Plan for Renewable Energy and Rural Development
2009	National Energy Policy; Rural and Renewable Energy
2009	Division of Electricity and Renewable Energy Created within the Ministry of Lands, Mines and Energy
2010	Signing of the IRENA Statute; Liberia Energy Sector Support Program

Source: IRENA (2011).

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