Renewable Energy and Developing Countries: The Cases of India and Nigeria

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Introduction: Climate Change and Developing Nations

Climate change will have a disproportionate affect on developing nations. Economic dependence on agriculture, tropical geography, rapid population growth, poverty, and limited capacity to cope with an uncertain climate all make developing nations more susceptible to the damaging effects of climate change than developed nations.

Climate change is not only limited to the idea of a warming planet, but also increased variability of climate. Developing nations are more greatly exposed to climate change effects, particularly through heavier economic dependence on agriculture and dependence on predicable rainfall. Concentration of their economy on a single sector makes these nations more sensitive to the effects of climate change, due to their inflexibility to switch to other, less climate-sensitive industries. They also lack the ability to adapt to these changes through insufficient infrastructure and water management systems, underdeveloped financial markets, low incomes, and generally poorer public services. Having limited financial resources becomes especially important since the impacts of climate change can be compounded (Stern 2007).

Thus, efforts to mitigate climate change are of prime importance to developing nations. While richer, developed nations are the ones who are currently emitting the most carbon into the atmosphere, the United States Environmental Protection Agency (EPA) estimates that by 2015, the amount of total greenhouse gases emitted into the atmosphere by developing nations while surpass that of developed nations. And so while developing nations may not have been the initial perpetrators of a changing climate, they will soon be the heaviest contributors to it. A large and growing responsibility to contribute to climate change mitigation will increasingly rest on their shoulders.

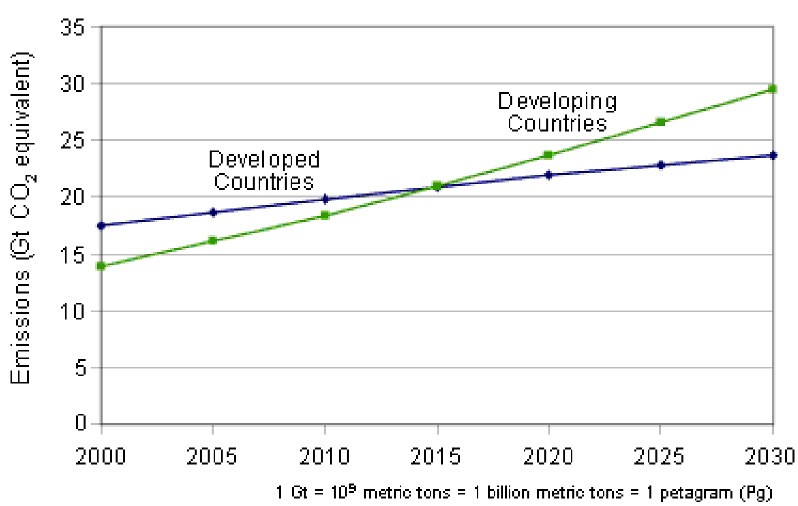

Figure 1: Total greenhouse gas emissions by region (Global Greenhouse Gas Data)

However, the term “developing countries” can be quite broad, given the different countries and economic situations that lie under this single umbrella term. In this paper we seek to analyze two different situations, India and Nigeria, in order to highlight that while both of these countries may differ in size, population, economy, and energy needs, both have the resources and ability to contribute to mitigating climate change in their own ways. And indeed many of these resources, though recognized, are currently not being tapped.

India has a large and rapidly growing population that demands greater energy consumption each year. We will explore how India can work to meet these growing demands through increased use of biomass for electricity generation. This underutilized source of electrical energy can be a major factor in meeting in the growing energy demands of both the urban and rural landscapes. We will then explore Nigeria, rich in oil but facing issues of inadequate access to electrical power, and where the development of solar power could be a boon to the nation's energy needs. We will look at the advantages and barriers to the adoption of solar power in Nigeria.

By exploring two case studies of renewable energy in two very different, yet both "developing" nations, we hope to illustrate the diverse challenges that developing nations face in mitigating climate change and making the move toward renewable energies. And we hope to present solutions to these challenges in the context of these two different countries.

RENEWABLE ENRGY AND ECONOMIC GROWTH IN INDIA

Growing Population, Economy, and Energy Demand

From 1.09 billion in 2005, India's population is expected to reach 1.46 billion by 2030, rising faster even than China's. Most of this growth will take place in urban areas, leading to larger strains on the electric grid. During this same period, power generation capacity will move from 144 GW to 400 GW, mostly from the continued burning of coal (WEO 2007).

All this power will be used to drive India's rapidly growing economy (the 13th largest in 2006), which grew 9% in 2005 and is expected to keep this pace for the foreseeable future (WEO2007). In order to sustain this growth and to meet human development and poverty eradication goals by 2030, India will need to increase electricity generation 5- to 6-fold over 2003 levels (Planning Commission 2006). And though India's economic growth will pull many of its citizens into the middle class, it will maintain a large low-income labor pool that will continue to help maintain economic growth. Meanwhile, India's growing middle class will demand more power-intensive goods and services such as cars and electrical appliances, driving up energy demand even further. In addition to domestic consequences of growth, a rapidly expanding Indian economy is also beneficial to the surrounding world. A richer India is a larger consumer for foreign industries, and a more productive India creates more for the rest of the world to consume. India's growth not only furthers its own domestic development but does so while integrating into the world economy. This all depends, however, on satisfying a growing energy demand, specifically electric power generation (WEO 2007).

Current Status of Energy and Electricity in India

India is the world's fifth largest consumer of energy. By 2030, it is expected to be the third largest. Much of this comes in the way of rural biomass – wood and waste fuels used for individual cooking and heating. But by 2030 the number of Indians using rural biomass will drop from 668 million to 470 million, and this decrease in rural-sources of energy coincides with an increase in the share of Indians with access to electricity from 62% to 96%. Increasing electric capacity, and the sources of power generation, will be of prime importance in the next 20 years (WEO 2007).

India is currently both the third largest consumer and producer of coal in the world, accounting for more than half the country's overall energy consumption and about 70% of electricity generation. In addition to coal, natural gas is playing an increasing role in generation, and with a new civil nuclear agreement signed in 2005 between the United States and India, nuclear power generation is expected to rise to in the coming years (Zissis 2007).

Though India's vast, tropical landscape provides rich conditions for renewable sources of energy such as solar, wind, hydro, and biomass, the share of renewable energy as a source of electricity production pales in comparison to conventional thermal sources of generation. This underutilized potential will play a crucial role in India's energy future. Hydro currently contributes the largest share, but despite rising energy consumption hydro production has remained mostly stable over the past 20 years (Planning Commission 2006). Small hydro plants (with capacities up to 25 MW) show promise: a total of 203 small hydro projects with an aggregate capacity of 468 MW are currently underway (Bhattacharya 2009). However, even if the full potential of hydro is achieved, it will contribute only 2% of total energy needs (Planning Commission 2006). Solar production, despite subsidies early on, has similarly lagged. While solar photovoltaic production increased 6 fold worldwide between 2000 and 2005, production in India has only increased by 4 times to a total capacity of 40 MW. Installed wind capacity in India, however, currently ranks 4th in the world at 6270 MW. Aided by India's large coastline, off-shore wind generation also shows great potential (Bhattacharya 2009).

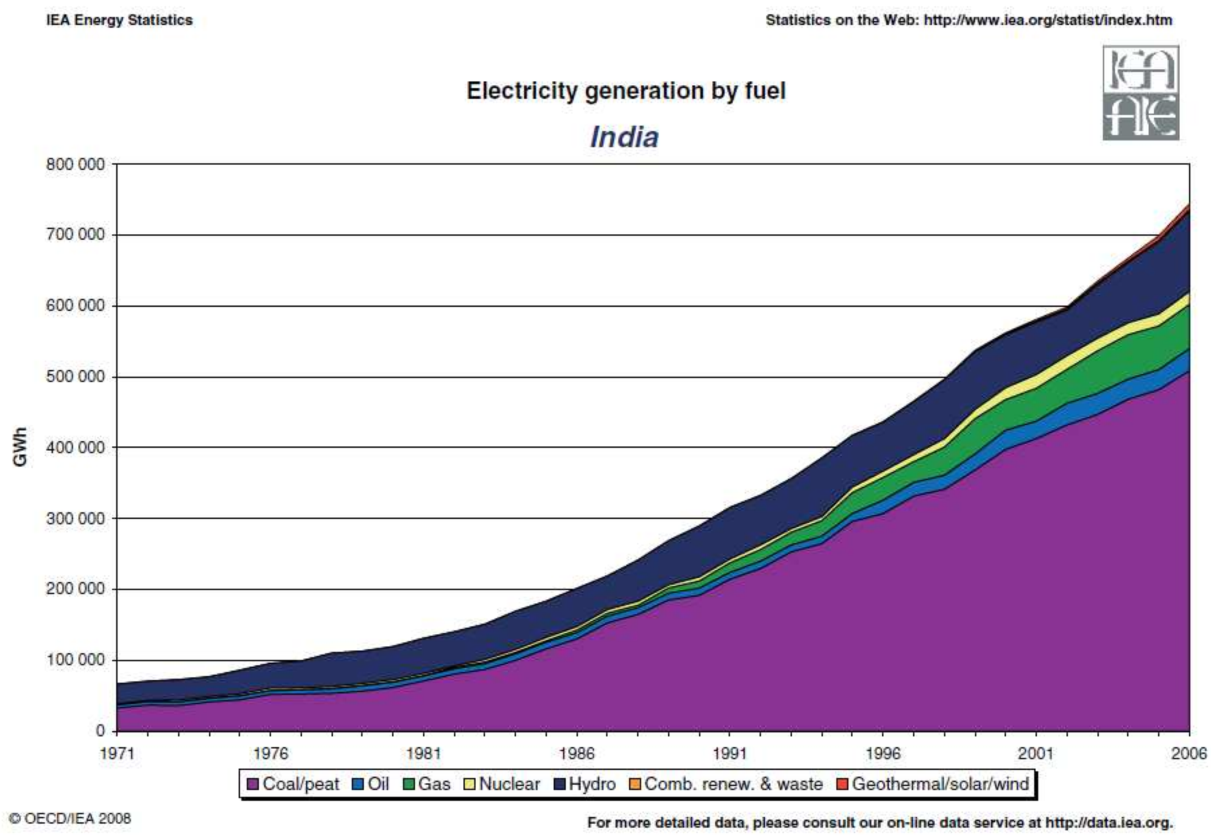

Figure 2: Electricity generation by fuel (IEA Energy Statistics)

Emissions

Despite promising potential for renewable energy, India's abundance of coal and growing energy demand ensure that coal will continue to be the major source of electricity generation, and as a result CO_2 emissions in India will continue to grow. According to the Energy Information Administration (EIA), India emitted 1,300 million metric tons of CO_2 from energy related sources in 2006. More telling is the increase in emissions over time: India's CO_2 emissions have roughly tripled since 1981 while worldwide emissions have only doubled during the same period. As of 2005, India holds a total of 62,278 million short tons of coal reserves (EIA). This abundant, domestic source of energy at a time when energy demand is steadily and rapidly increasing will be difficult to resist, but it comes at the cost of increased emissions. And given India's growing population, number of poor, temperate climate, long coastlines and tropical climate, India is on a course to greatly contribute to it's own potentially catastrophic burdens of climate change.

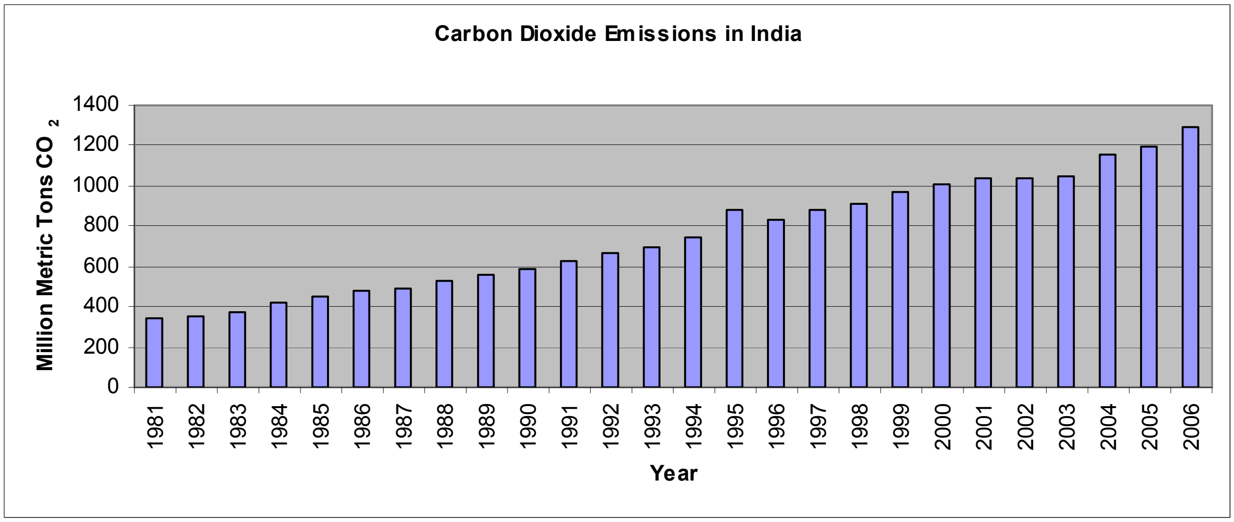

Figure 3: CO_2 *emissions in India (EIA)*

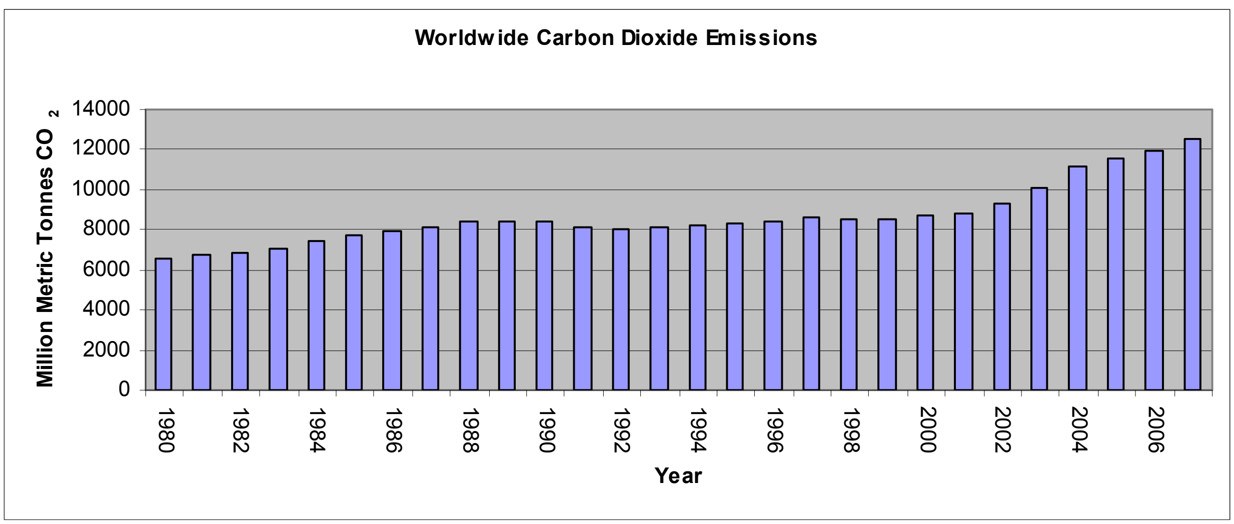

Figure 4: CO_2 *emissions worldwide (EIA)*

The Role of Biomass

The remaining source of electricity generation with great potential is the combustion of biomass materials. India already has a long history with biomass. Rural populations depend on the combustion wastes, either directly or through gasification, for much of their energy needs. By one estimate, 72% of India's 192 million households depend on biomass. In rural India, 90% of households depend on biomass for their cooking needs, and a full 72% of households are currently located in these rural areas lacking proper infrastructure. An additional 27% of urban households also depend on biomass (Bhattacharya 2009).

This independent use of biomass, however, is subject to inefficiencies. The collection of biomass, done mostly by women and children, occupies precious daylight hours and puts strains on opportunities to join the workforce or receive education. Direct burning of biomass for cooking is also less efficient than using an electric stove. Using electricity for cooking needs has 75% efficiency while burning wood for cooking has 15% efficiency, and the fumes released from the burning of biomass can be harmful if not properly ventilated (World Bank 2004).

Using biomass for the generation of electricity through standard power generation and cogeneration plants has the potential to correct some of these inefficiencies and provide some of the increased electric capacity that the rapidly growing Indian economy will greatly need in the future. As of 2006, India had 466.5 MW of grid-connected power generation through agro-residues and plantation biomass, and an additional 11.5 MW of off-grid generation. However, according to the Ministry of New and Renewable Energy (MNRE), new estimates of India's biomass power potential in the midterm (up to 2030) reach upwards of 123,000 MW (Bhattacharya 2009).

Power Potential in India (MNRE estimates)	
Biomass power (medium term - up to 2030) in MW	
Agro-residue	(incl. below)
Plantation biomass (from 30 mil ha of wasteland yielding 10 metric tones/ha/year with 40% efficiency	111000
Bagasse-based cogeneration	5000
Wastes	7000
Total	**123000**
Old estimates	
Biomass power (medium term - up to 2030) in MW	
Agro-residue	16000
Plantation biomass (from 20 mil ha of wasteland yielding 10 metric tones/ha/year with 30% efficiency	45000
Bagasse-based cogeneration	5000
Wastes	7000
Total	**73000**

Table 1: Biomass Potential in India (Bhattacharya 2009)

A Challenge both Urban and Rural

The challenge of increasing electric capacity in India can be viewed in two different contexts: urban and rural. In the urban scenario, the growing cities will increase electricity demand in the near future. In the rural areas, providing electricity will help develop communities, small industries, and bring modernization. Both can do so in a sustainable fashion that reduces carbon emissions by taking advantage of the country's vast biomass resources. The MNRE has stated support for expanded biomass electricity generation, emphasizing its increased use both in urban and rural areas. For urban biomass generation, the MNRE has laid out the following objectives (Tiwari 2005):

i. To encourage the deployment of biomass energy systems in industry for meeting thermal and electrical energy requirements.
ii. To promote decentralized / distributed power generation through supply of surplus power to the grid.
iii. To conserve the use of fossil fuels for captive requirements in industry.
iv. To bring about reduction in greenhouse gas emissions in industry.
v. To create awareness about the potential and benefits of alternative modes of energy generation in industry.

The MNRE has also laid out objectives specifically for biomass gasifier plants in rural areas with the intention of promoting distributed/off-grid power generation. The objectives for this program are (Khare 2009):

i. Biomass Gasifier based Distributed / Off-grid power for rural areas for meeting unmet demand of electricity in electrified / to be electrified villages in potential sites preferably village clusters identified by the states which have potential of biomass.
ii. Grid interactive MW level biomass gasifier based power project with 100% producer gas engine.
iii. To support and enlarge activities, through awareness creation, publicity measures, seminars / workshops / business meets / training programme etc. and expand local manufacturing capacity and service facilities.

In the following two studies, we take a closer look at the problem in these two contexts. First we will look at the urban scenario and compare the costs electricity from a biomass plant versus the cost of electricity from a coal-fired plant. Then we will turn to the rural scenario, where we will analyze the costs of providing electricity from a gasifier plant versus the costs of electricity from a coal-fired plant.

Biomass in Urban India: Comparing Costs of Biomass Electricity vs. Coal Electricity

The rising environmental concern of increased carbon emissions has left India with a tough decision to make about its economic and energy future. Using non-renewable coal generation plants can achieve economies of scale to produce energy and support a stable economic growth, but at the cost of increasing carbon emissions. India has long been considering biomass as a viable alternative to non-renewable resources, however a strong disadvantage of the biomass technology is the capital cost required. One must look at the costs and benefits of the two different technologies, coal and biomass, and see what solutions are most economical for growth in the state of India.

India can be divided into two different categories of regions, urban and rural. To focus on the urban region of India we will look at the Maharashtra state. This well developed industrial area gives us an insight into energy policies the country could use in the development of industrial parts of the country. Maharashtra is the second largest state in India by population, and first by electric capacity. 13% of India's electrical generation is in the state of Maharashtra, but the demand still far exceeds supply due to inefficiencies in the process (Central Electricity Authority). In 2003 Maharashtra produced 10,979 MW of electricity, falling short of the demanded amount 13,697 MW during peak hours (Maharashtra Energy Development Agency). Maharashtra currently still holds an energy deficit. Demand in 2009 will reach 20,555 MW, while supply only provides 20,415MW during peak hours (Central Electricity Authority). Maharashtra has taken steps to keep up with its increasing electrical demands, but it still needs to create more energy to be available to sustain economic growth. Also of concern are the decreasing supply of resources and questions over the type of electrical infrastructure India should use to support its growth in the future. If India plans to achieve 6-8% economic growth in the next 10 years, then the state of Maharashtra will need to increase its energy production by 7% on average each year (India Energy Portal). Thus, by 2020, the electrical demand will be 43,266 MW in 2020.

Year	Energy Demand (MW) during Peak Activity
2009	20,555
2010	21,994
2011	23,534
2012	25,181
2013	26,944
2014	28,830
2015	30,848
2016	33,008
2017	35,318
2018	37,790
2019	40,435
2020	43,266

Table 2: Megawatts Required Projections (International Energy Studies)

The state of Maharashtra will need to expand the existing 20,555 MW to 43,266 MW, requiring the implementation of 22,711 MW in electrical plants in the next 10 years. We will look at two different options in attempt to identify the best economic choice for the state of Maharashtra given this expected increase in electricity demand needed to sustain its economic growth – the costs in using coal plants and biomass plants to produce electricity in the Maharashtra state in 2020.

There are many different costs associated with the production and delivery of electricity. The three main costs are capital costs, transportation costs, and fuel and operating costs. The transportation costs of delivering biomass can vary upon the method used, the fuel, and the distance needed to deliver. Pipeline, truck, and rail are the three most common and efficient methods to transport biomass.

Year	Percent Increase to 2009 Dollars
2000	25.5%
2001	22.1%
2002	20.2%
2003	17.5%
2004	14.40%
2005	10.70%
2006	7.20%
2007	4.30%
2008	.4%

Table 3: Inflation Rates in US (US Inflation Calculator)

Type	$/Ton	Ton/MW	$/km	$/(MW*km)	Fixed Costs/ (MW)	2009 Dollars
Pipeline	1	1.62	16	25.93	0	27.03
Truck	1	1.62	.13	.2106	8.68	.2258
Rail	1	1.62	.03	.0486	48.63	.05215

Table 4: Biomass Transportation (Short 2009)

Using this data to calculate the cost to move enough biomass fuel to produce 1 MW of energy, we find that rail has the lowest variable costs. Pipeline is the most expensive, so it is not a useful option. Truck has a higher variable cost than rail, but a much lower fixed cost. We see that truck will be the cheapest option up to a certain distance, when the low variable costs of rail become cheaper than truck. This occurs between 130-140 km (136km), so when calculating the total costs for the use of biomass, we will use truck for the anything under 130 km, and rail for any distance over 130 km.

$/ton	Ton/MW	$/MW*mile	$/MW*km	2009 Dollars
9.01	.4	3.60	5.80	7.28

Table 5: Coal Transportation (Energy Information Administration)

The costs associated with coal transportation are much more established than those of moving biomass. These costs are also much easier to calculate since coal is normally taken from the same source – a centralized mining point. The average cost to transport a ton of coal since 1980 was 9.01 $/ton. Since it takes .4 ton to produce 1 MW of electricity on average, it takes about $3.60 to transport enough coal to produce 1 MW of electricity 1 mile, giving us $7.28 in 2009 dollars to transport enough coal to produce 1 MW of electricity 1 km.

Another input in the production of electricity is fuel and operating costs. In the next 10 years there is much uncertainty on the costs of inputs of biomass and coal. As the markets for each fluctuate, the prices for each remain volatile; the choices on which fuel or plant to use changes. For this reason, we will look at ranges of biomass fuel (sugar stock, wood chips, or forest reserves) and of coal prices to see where the optimal choices lie. For biomass we will look at prices between $40-100 per MW, and between $20-30 per MW_2 for coal (International Energy Agency).

Fuel	Price Range /MW
Biomass	$40-100
Coal	$20-30

Table 6: Fuel Prices (International Energy Agency, Short 2009)

The capital costs play the biggest role in the development of electricity. Capital costs to build plants far exceed the costs of fuel, operation, or transportation. The cost is also dependent on more variables, such as financing, location, and building logistics. For this reason we will use a much wider range of values to construct biomass and coal plants.

Plant	Price Range /MW
Biomass	$645,000 – $860,000
Coal	$700,000 - $1,250,000

Table 7: Capital Costs (Bio Energy Association of Sri Lanka, International Energy Studies)

To analyze the data we will vary the 3 variables (transportation costs, fuel and operation costs, and capital costs) to get the total costs of producing electricity either from biomass or from coal. We notice that the most expensive case in which all three factors (capital, fuel and operation, and transportation) are maximized, the most expensive biomass option is $19.997 billion dollars. It is only economically viable to use coal plants when the price of capital costs for coal is under $860,000 per MW. In all other cases, biomass is cheaper to produce per MW. We notice in our analysis that the costs are heavily dependent on capital, since this is the largest factor of production by orders of magnitude. The reason coal production costs may be so high in the future is due to uncertainty. India has a fast growing economy and the supply of non-renewable resources is limited. With this in mind, governments and firms are uncertain on the future of coal as an energy source. Also, the rising concern over policies with carbon emissions may have producers worried about the type of fuel they want to use for electrical production.

Biomass in Rural India: Comparing Costs of a Biomass Gasifier vs. Coal-fired Electricity

In this next study we will explore the challenge of meeting growing energy needs of rural India. This study is based off of a case study done by N. H. Ravindranath, H. I. Somashekar, S. Dasappa and C. N. Jayasheela Reddy at the Centre for Sustainable Technologies, Indian Institute of Science, Bangalore 560 012, India. This case study will be the basis of a number of the conclusions that we draw from in our own analysis. However, our conclusions will be based off further research and independent calculations. This case study was conducted in Hosahalli Village, a village of Kunigal Taluk in the Tumur district. Hosahalli was a non-electrified village consisting of a population of 218 people until a wood-fueled dual-mode biomass gasifier system was introduced. The aforementioned case study analyzes the effects that the gasifier system has had on the village. A biomass gasifier partially combusts the biomass under a controlled air supply leading to the generating of a producer gas consisting of the combustible gases H2, CO and CH4. This gas can then be used as fuel in an internal combustion engine for electrical and mechanical operations. Furthermore, "Biomass gasifier systems based on woody biomass, raised on wastelands, have been shown to have the largest potential to meet rural electricity needs in most parts of India"(Indian Institute of Science). Thus, we purport that the findings of this case study may be applicable to other similar rural areas of similar scale.

Commissioned in 1997, the installed capacity of this gasifier is 20 kW. The system ran about 300 days for approximately 15 hours a day. The findings and results and explanations of the variables of the case study are listed below:

Load (kW)	Diesel cost (Rs/h)	Biomass cost (Rs/h)	Engine (Rs/h)	Gasifier (Rs/h)	Labor cost (Rs/h)	Total cost (Rs/h)	Cost/kWh (Rs/kWh)
6	16.4	9	5.42	0.98	6.25	38.05	5.85
7	21.1	10.5	5.42	0.98	6.25	44.25	4.92
8.5	18.74	10.5	5.42	0.98	6.25	47.87	4.65
11.5	22.26	15	5.42	0.98	6.25	49.91	3.56
15	25.77	18	5.42	0.98	6.25	56.42	3.52
20	42.17	25.5	5.42	0.98	6.25	80.32	3.34

Table 8: Cost: Wood = Rs 0.75/kg; Diesel + transport = Rs 23.45/l; Engine maintenance = Rs 5.42/h; Gasifier maintenance = Rs 0.98/h; Operator wage = Rs 6.25/h.

The cost per kWh of electricity is calculated by taking the fuel and operations and management costs expended at different loads on the power generation system in Hosahalli. Plant load factor is one of the key factors contributing to the cost of electricity, as the cost per hour of operation is same for the system irrespective of the load, particularly the operator cost and start-up diesel use. Engine maintenance accounts for the cost of all the consumables, such as lubricating oil, oil filters and gaskets used during the maintenance of the engine-generator set and the electrical distribution. Similarly, gasifier maintenance includes all the costs involved in operating the gasifier system, such as the gaskets and filter changes. The labor cost includes the operator's monthly salary. Biomass cost includes transportation from the forest to the power plant and fuel preparation. The biomass feedstock preparation is carried out by the village households manually.

From this data set we are able to draw conclusions about the cost of coal versus the cost of biomass energy from a gasifier system in a rural area. Before any conclusions are analyzed, the first important calculation we make is to figure out how many kW were produced per hour. In order to do this, we simply divide total cost (Rs./h) by cost per kWh (Rs./kWh):

(Rs./h)/(Rs./kWh) = (Rs./h)*(kWh/Rs.) = kWh/h

Thus dividing the last two columns of the data in this way, we obtain:

kWh/h
6.504274
8.993902
10.29462
14.01966
16.02841
24.0479

Table 9: Kilowatt-hours produced per hour

However, something that the data above is missing is the capital cost of implementing one of these systems. Fortunately, this system is not very large in size or capacity so the capital costs of this gasifier are also not large; it is estimated by the World Environment Library that the capital cost of this exact system was "Rs. 63,600; in contrast, the capital cost of an equivalent engine running on diesel is estimated to be around Rs. 39,600" (World Environment Library). If we assume that this system's capital cost was set to be paid off in the 6 years from 1998-2003 due to a loan with an annual payment and an interest rate of 6% (icicibank) then the cost per kWh is found below:

1. We first find out how many rupees per year must be paid to pay off the loan:
   We can find this by using an annuity formula:
   PV = pmt * ((1 - (1 + r) ^ (-n)) / r)
   let PV=63,600 Rs, Pmt=payment, n=6, r=.06.

   Solving for payment, we get pmt = PV/((1 - (1 + r) ^ (-n)) / r)
   Plugging in the numbers yields: 12933.86 Rs. per year for 6 years.
2. By assuming that the plant is open for 15 hours, 300 days a week, we can calculate the cost per hour for the loan by:
   300 days * 15 hours = 4500 hours/ year
   12933.86 Rs / 4500 hours = 2.87 Rs / hour
3. If we assume that only one load amount is going to be used during the year then we can find the cost per kWh by taking the total cost per hour from each load and adding 2.87 Rs, and then dividing the total by the output as measured in kWh/h, we can find the cost per kWh.

Load (kW)	Total cost (Rs/h)	capital (Rs/h)	kWh/h	Rs/kWh
6	(38.05 +	2.87) /	6.504274 =	**6.29**
7	(44.25 +	2.87) /	8.993902 =	**5.24**
8.5	(47.87 +	2.87) /	10.29462 =	**4.93**
11.5	(49.91 +	2.87) /	14.01966 =	**3.77**
15	(56.42 +	2.87) /	16.02841 =	**3.70**
20	(80.32 +	2.87) /	24.0479 =	**3.46**

Table 10: Cost per kWh

From these calculations, we can see the cost per kWh of operating the gasifier system with the fixed costs of the plant included. This would be the cost of the plant only for the 6 year payment period. After six years when the plant is paid off, the price per kWh would return back to the levels shown in Table 1. To further this study, it would be beneficial to compare the costs of this gasifier system with the costs of energy produced by coal. Coal costs around 2.5 Rs/kWh (Energy Alternatives India). However, this data is taken from 2009 so we need to adjust this data to account for factors of inflation on the price of coal based energy. Thus we are assuming that the only factor that has had a significant effect on the price of coal based energy in India is inflation. This assumption is being made because after much research, no evidence was found to disprove this assumption. Assuming further an average inflation rate of about 8% since 2003 (CIA World Factbook), we are now able to discount the price per kWh in 2009 to its equivalent 2003 levels.

The following formula is used to discount backwards:

Past value = future value / ((1+r)^n) where r = inflation rate and n = number of years from 2003-2009:

$$2.5 / ((1+.08)^6) = 1.58 \text{ Rs. / kWh}$$

Comparing this value (1.58 Rs/kWh) to the price per kWh from the gasifier system, we see that the energy from the gasifier system at a 20 kW load (its cheapest Rs./kWh option) is a little more than twice as expensive as coal based energy when the capital costs are included, and just about twice as expensive when capital costs are not included. According to some energy economists, it is perfectly fine for energy from renewable sources to be twice as expensive as coal based energy:

"An important aspect of [the Hosahalli] project is that the villagers are prepared to pay over twice as much for their electricity because: (a) the supply is reliable; (b) it provides ancillary benefits (clean drinking water, flour mill etc.); (c) quality of supply; and (d) of emergence of self-reliance (the formation of a village management committee) (Ravindranath, in press)" (World Environment Library).

These show that there are many positive externalities associated with the implementation of a gasifier system in rural areas. Moreover, the implementation of a gasifier system such as the one in Hosahalli Village creates jobs, such as plant operators, for villagers.

And through further research we may be able to bring the cost of electricity down to a more competitive rate compared to the price of coal-based energy.

First, let us analyze the effects on cost per kWh by increasing the load size. We notice from *Table 8*, that as the size of the load increases, the cost per kWh decreases. If we assume that load size and cost per output are linearly related, we can run a linear regression, and fit a line to the data. From *Figure 5* below it is apparent that as load increases by one unit, the difference between load and cost per kWh also increases by approximately one unit, which is the reason why we can assume that load and cost per kWh are approximately linear. However, since load and cost per output are not exactly linear from our data as seen in *Figure 5 below*, we cannot assume that this model will be approximately linear throughout all load amounts. We must limit our load range to ensure approximate normality in our model. Our range will be from 0 kW to 40 kW. Our data only goes up to 20 kW, and since it would be unwise to attempt to draw conclusions from data points that are greater than twice the actual data, we will not draw conclusions from anything greater than 40 kW. Furthermore, to ensure that we have conservative results, we will use the cost per kWh calculation that includes capital.

Load (kW)	Cost/kWh (Rs/kWh)	Load - Cost/kWh
6	6.29	-0.29
7	5.24	1.76
8.5	4.93	3.57
11.5	3.77	7.73
15	3.7	11.3
20	3.46	16.54

Table 11: Load – cost/kWh

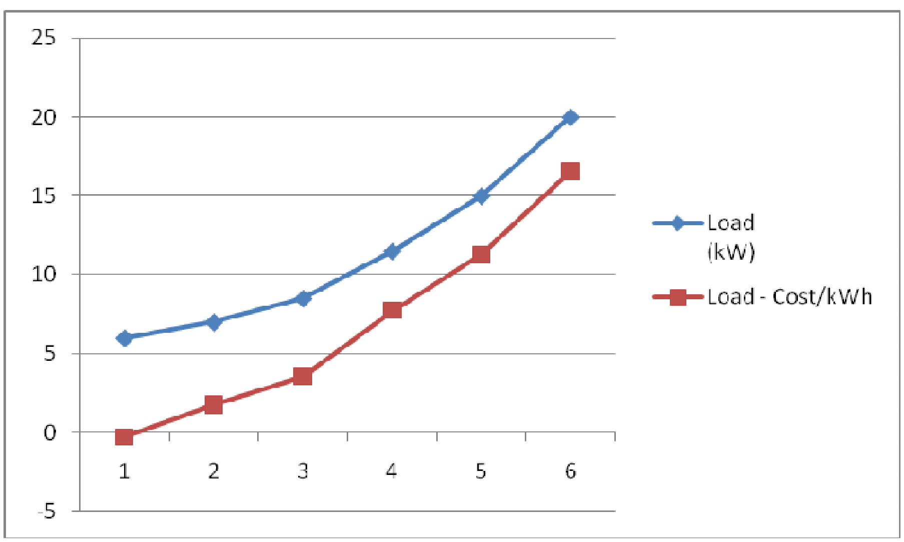

Figure 5: Load – cost/kWh projection

The results from the linear regression are as follows:

```
. regress ccost  load  (ccost = cost per kWh including capital)

   Source |       SS          df        MS              Number of obs  =  6
-------------+------------------------------            F(  1,     4)        =  12.99
    Model |  4.71435564    1   4.71435564           Prob > F           =  0.0227
 Residual |  1.45139366    4     .362848414          R-squared        =  0.7646
-------------+------------------------------            Adj R-squared   =  0.7058
    Total |   6.1657493     5    1.23314986          Root MSE         =  .60237

------------------------------------------------------------------------------
    ccost |    Coef.       Std. Err.       t       P>|t|        [95% Conf. Interval]
-------------+----------------------------------------------------------------
   loadkw |  -.1810429   .0502265    -3.60   0.023    -.320494   -.0415918
    _cons |   6.616819   .6200819    10.67   0.000    4.895196    8.338442
------------------------------------------------------------------------------
```

From our regression output, it is apparent that both of our coefficients are statistically significant as seen from the high |t-value|. Also note the R-squared value of 0.7646. From this number we see that 76% of the variation in the residuals of the cost per kWh variable are explained by load. However, this means that 24% of the variation is explained by other factors not included in the regression. Although 76% is significant, it shows that it is not robust. This is precisely the reason that we have limited our load range to 40 kW. In a smaller range, our results will be equivalent to the actual values, whereas if we allowed our linear model to extend further our results would not be equivalent or significant. From the data above, our regression results are as follows:

Cost per kWh(Rs/kWh) = 6.62 – 0.18 * load(kW)

To find out at which load the cost per kWh from our woody biomass gasifier system would equal the cost per kWh of coal, we simply set the cost per kWh on the left side of the equation to 1.58 Rs/kWh, and then solve for load.

Load(kW) = (1.58 Rs/kWh – 6.62) / -0.18 = 28 kW

Since 28 kW falls within our range, we see that if a 28 kW load biomass system is used throughout the entire year, the cost per kWh would be the same as the average cost per kWh used in coal based systems. Keep in mind though that 1.58 Rs/kWh is probably a conservative number for this study since a coal based system would probably be a little more expensive considering that it would cost money to connect Hosahalli Village to the grid. Thus the people of Hosahalli Village would likely pay slightly more than 1.58 Rs/kWh to obtain their coal based energy.

From the above data, at a load of 28 kW or higher, a woody biomass system similar to the one in Hosahalli Village would cost just as much or be cheaper per unit than a coal based system. This result is only valid by making assumptions. We must assume that the capital cost of setting up a 28 kW load gasifier system is relatively similar to the capital cost of the one in Hosahalli Village. Also, we must assume that diesel cost is also linearly related to load, otherwise our theory of linearity that we made above will be wrong, and our model invalid. We must also assume that other places where a similar biomass system could be incorporated are also of a relatively similar distance to a forest, which as research points out, is the case for many rural areas in India (World Environment Library). In the majority of cases, these assumptions hold, but as with any assumption there are instances where they fail. So although they are valid in many cases, they are not robust. Thus our result of a woody dual mode gasifier system at a load of 28 kW being equivalent in cost per output to a coal based system is a fairly valid calculation, and is worth consideration. It is not, however, robust and it should not be assumed to be correct in all cases. Thus to further show that a gasifier system should be used in rural areas in India, we will analyze the costs of using a regular 20 kW load gasifier system like the one in Hosahalli Village with the price for saved CO_2 emissions taken into account.

From the data found in the case study (Indian Institute of Science), we see the output data of energy used in the village per year:

	2003	2002	2001	2000	1999	1998
Total electricity generated kWh/yr	21977	21557	16251	12489	12884	12023

Table 12: Total electricity generation kWh/yr

One thing of importance here is that yearly energy output is increasing each year. Assuming that the biomass gasifier is capable of operating at a load of 20 kW for the entire year, and assuming that the gasifier operates 300 days a year and 15 hours a day, then by multiplying the output obtained in *Table 9* for a 20 kW load by 4500 hours (300 days * 15 hours), we will obtain the maximum capacity of energy per year for this gasifier system:

24.0479 kWh/h * 4500 hours = 108215.6 kWh/year

We see for the output of data in *Table 12* that on a yearly basis, this gasifier system is not producing nearly their maximum potential of energy. However, we do see that they are producing an increasing amount from year to year. If we assume that the energy output of this gasifier system increases in a linear fashion from year to year, we can run a linear time series regression to estimate how much energy we think will be produced in the future. The result of our regression is as follows:

Index is defined as follows: 1998=1, 1999=2, 2000=3, 2001=4, 2002=5, 2003=6, etc…

.regress output index

```
    output |      Coef.     Std. Err.       t       P>|t|     [95% Conf. Interval]     R-squared     =  0.8669
-------------+----------------------------------------------------------------
     index |   2272.886   445.3451     5.10    0.007      1036.409    3509.362
     _cons |    8241.733    1734.37     4.75    0.009       3426.35    13057.12
------------------------------------------------------------------------------
```

Here we see that we have large and significant t-values, and the R-squared is also significant. So we have obtained the following formula to help predict energy output in the future:

Output = 8241.73 + 2272.89 * index

From this equation the following predictions of energy per year until 2015 are as follows:

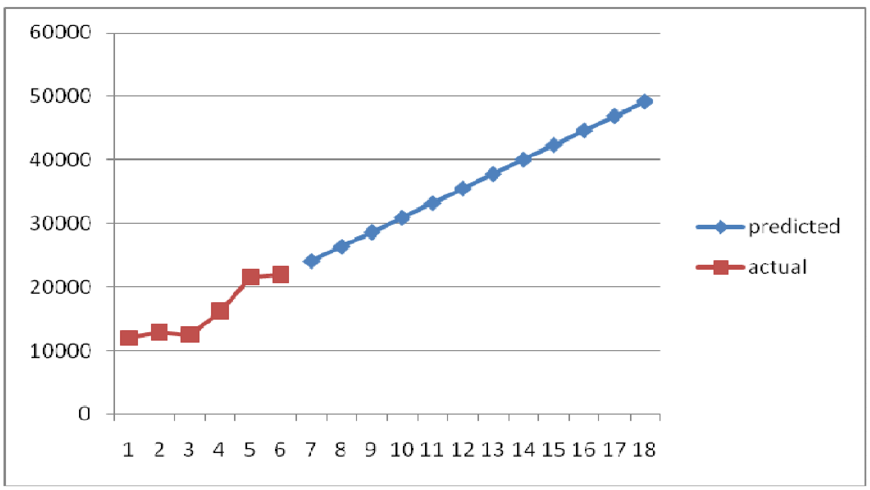

Figure 6: Energy capacity per year

1998	1	12023	2008	11	33243.48
1999	2	12884	2009	12	35516.37
2000	3	12489	2010	13	37789.25
2001	4	16251	2011	14	40062.14
2002	5	21557	2012	15	42335.02
2003	6	21977	2013	16	44607.91
2004	7	24151.94	2014	17	46880.8
2005	8	26424.82	2015	18	49153.68
2006	9	28697.71			
2007	10	30970.59			

Table 13: Energy capacity per year

From the above predictions we see that the amount of energy used in 2015 still does not exceed the maximum amount of 108,215.6 kWh, which shows that our assumption of a linear increase does not violate our range of 108,215.6 in the short run. So our prediction is relatively accurate in the short run. From these predictions, we can compute the amount of emissions saved.

A report in India from 2009 has claimed that each carbon credit is selling for around 14 euros (India Times). 14 Euros is equivalent to 975.38 Rs. From the predictions above of energy output, we see that 35,516.37 kWh of energy should be generated in 2009. By discounting forward the price per kWh from 2003 using an inflation rate of 8% as before, we find that the 2009 price per kWh of coal based energy is 2.5 Rs/kWh (obtained previously), and for a 20 kW load, the price per kWh from the gasifier system in 2009 (after the cost of capital has been paid off) is:

3.34 (from table 1) * (1+.08)^(2009-2003) = 3.34*(1.08^6) = 5.30 Rs/kWh

Now that we have cost in 2009 terms, we can evaluate how much it would cost to produce 35,516.37 kWh of energy using coal based energy, and compare that with the cost of producing the same amount of energy using the gasifier system subtracted by the price of the carbon emissions saved. To calculate the price of saved carbon emissions we turn again to the case study from the Indian Institute. "Every kilowatt hour of electricity generated based on sustainable biomass supply, leads to reduction in CO_2 emission by 1.0 kg" (Indian Institute of Science). Since 1 carbon credit equals 1 ton of CO_2 emission saved, and since 1 ton = 1000kg = 1000kWh (as seen above), then 35,516.37 kWh of energy as predicted for 2009 use is worth 35,516.37 / 1000 = 35.5 tons of CO_2 emissions saved, which is equivalent to 35.5 carbon credits. Since India has been selling these carbon credits for about 14 euros, or 975.38 Rs. per carbon credit, they should be able to sell their 35.5 carbon credits and make 35.5 * 975.38 = 34,626 Rs. in 2009. This 34,626 Rs. is the amount that is earned by using the gasifier system due to the reduction of carbon as compared to the amount that would be used if the same amount of energy were generated using a purely coal based system. However, the cost of using a purely coal based system in 2009 would only be:

35,516.37 kWh * 2.5 Rs/kWh = 88,790.93 Rs

Whereas the cost of the gasifier system would be:

35,516.37 kWh * 5.30 Rs/kWh = 188,236.76 Rs – 34, 626 Rs. (the amount that they can sell their carbon credits for) = 153,610.76 Rs

Thus the ratio cost of biomass to coal before taking the savings from carbon credits into account is 2.12:1, but after taking the carbon credits into account is 1.73:1.

From the above results we see that the cost per year of using the gasifier system is a little less than twice the cost of using a purely coal system. If we continued these calculations for all the prediction years, we would consistently find the same ratio of the two costs per year since our prediction is based on a linear result, therefore our carbon emission prediction is also based on a linear result, thus causing our ratio to stay the same throughout the years when discounting forward both costs at the same interest rate. If we consider the former quote from the World Environment Library, which stated that the people would be willing to pay twice as much for the biomass energy because of the positive externalities associated with this system, then this system would be worthwhile for the villagers (World Environment Library).

With the increase in population and the increase in economic growth in India, we know that rural India will be demanding an increasing amount of energy. In this section, we have examined a case study from a wood fueled dual fuel gasifier plant in Hosahalli Village. We found the cost per kWh of the gasifier plant at a 20 kW load system including the plant's capital cost. From this data, the results of a linear regression revealed that given our assumptions for a 28 kW load gasifier plant would generate electricity at the same cost per kWh as the commonly used coal based system. However, this was assuming that a potential gasifier plant and its erection site match the assumptions made earlier. In the instance that our assumptions do not hold, an analysis of the cost per year of a predicted level of energy output was used to compare the cost of generating electricity using a coal based system versus the cost of generating electricity using a 20 kW load biomass gasifier system. Selling CO_2 credits reduced the cost per year making it affordable enough for people from rural areas to benefit from using a gasifier system. Even though the coal based electricity was cheaper, villagers would be willing to pay as much as twice as much for electricity from biomass sources due to the positive externalities that biomass electricity generates. Since the people would be willing to pay twice as much for gasifier based energy, the selling of carbon credits makes this alternative cheap enough to be implemented even at the 20 kW load. If our assumptions hold regarding the 28 kW load, this alternative will become even cheaper with the selling of carbon credits. Thus we see that for biomass rich rural areas demanding higher levels of energy output as their economy and population increase, biomass gasifier plants offer both a socially and economically effective source of energy. The authors of this paper recommend the implementation of these plants.

Recommendations for India

Based on these analyses, the authors of this paper recommend increased use of biomass for electrical generation in India. The benefits of stepping up biomass generation in the coming years include, but are not limited to, the following:

i. Decreasing greenhouse gas emissions while still increasing energy capacity and striving to meet increased energy demand
ii. Decentralizing electric power generation and improving access to electricity in rural areas to where it may not otherwise be feasible to extend the grid.
iii. Increase opportunities for women and children to join the workforce or pursue educational opportunities by alleviating their responsibility to collect biomass for personal use.
iv. Creating employment opportunities through the construction and operation of the plant.

However India will not be able to reach these benefits of biomass energy without the proper policies and implementation. With this in mind, and taking into account what we have discovered in our analyses, the authors make the following recommendations:

i. Focus on decentralization of electric power. This will be key in expanding electricity to currently non-electrified areas without incurring the often substantial costs of expanding the grid. Taking advantage of smaller, off-grid solutions can help meet increasing energy demand and continue fostering economic development.
ii. Provide subsidies for biomass plants in order to overcome the initially large capital costs. As we have seen, electricity prices from biomass plants can struggle to keep pace with coal-fired electricity prices, due mainly to large up-front capital costs.
iii. Attract investment, both foreign and domestic, into biomass technologies to work to bring down the prices of biomass electricity and make use of this abundant, currently underutilized renewable resource.
iv. Continued government support and actualizing government programs for biomass.

RENEWABLE ENERGY AND ECONOMIC GROWTH IN NIGERIA

Energy Accessibility and Alleviating Poverty

The purpose of this section of the paper is to explore the relationship between energy accessibility, economic growth, and solar energy provision in Nigeria. An analysis will commence by looking at the current use of energy, problems of accessibility, current policy interactions, and the potential for solar power in Nigeria. After the groundwork for this section is established, a synthesis of the data collected will provide a coherent framework of the way in which the authors believe solar power systems in rural areas of Nigeria can significantly ameliorate the problem of electricity accessibility, promote sustainable development, and help curb future greenhouse gas emissions of an emerging economy. The authors believe that extensive use of solar energy in Nigeria will have a dualistic effect of not only promoting economic growth and human development, but will do so in a way that will mitigate undesired levels of greenhouse gas emissions and consequently help alleviate climate change.

Before proceeding, a brief theoretical framework and rationale for the importance of this analysis should be mentioned. There has been a significant amount of research that has correlated economic growth with energy. Topics in this literature include relating GDP and GDP/capita to energy supply and economic growth's dependency on energy (Templet 1999; Ferguson, Wilkinson et al. 2000; Ikeme and Ebohon 2005). Regardless of the specific focus of researchers, most acknowledge the fact that the goal of poverty eradication and economic development require proper access to energy. This agenda is of significant importance to Nigeria where a large number of the population still lives in extreme poverty. According to the Human Development Report's (UNDP) Human Development Index, which looks at life expectancy, education levels, and standard of living (ie. purchasing power parity), Nigeria ranks 158th out of 177 countries (UNDP 2008). Furthermore, 70.8% of the inhabitants live on less than $2/day, 92.4% live on less than $1/day, and 70% of the people in the Niger Delta live without electricity, running water, hospitals, roads or proper housing (EarthTrends 2007). Lack of energy is especially serious in rural areas where an energy shortage has impeded small business and industrial development. Not only do basic necessities need to be met with proper access to energy, but if this large section of the population is going to participate in any form of sustainable economic growth, having a reliable source of energy to meet both daily domestic needs and economically oriented activities is a necessity. Consequently, as this economic growth occurs, it is imperative to be conducted in a way that does not contribute unsustainable levels of GHG's into the atmosphere. As mentioned before, this dualistic goal of economic growth through accessibility in developing countries must also be done with climate change mitigation strategies in mind. The feasibility and implementation of this strategy is to where this paper now turns.

The Energy Crisis in Nigeria

Nigeria's current and future plans for energy consumption and production have been significant issues due to the country's energy crisis. Nigeria has been struggling to overcome deficient supply electricity in many parts of the country. Much of this crisis is due to an inability to supply electricity throughout the country. Total electricity production in Nigeria was estimated in 2007 to be 23.11 KWh, yet electricity consumption is only 16.25 KWh (International Energy Agency (IEA)). The low level of consumption relative to production is a result of inefficiencies in the distribution of electricity causing less than 40% of Nigerian households having accessibility to the main electricity grid (Economist Intelligence Unit (EIU)). In rural areas (over 70 of the population) only 15% of households have access to electrify. Theft and antiquated systems of transmission and distribution of electricity result in heavy line losses. Total electricity generation in Nigeria is at around 2,000 MW while demand is estimated to be over 6,000 MW (Olukoju 2004). The consequences of the deficiency in reliable sufficient energy sources within the country range from economic barriers to growth, environmental hazards, and subpar living conditions. A study in 1998 found that the opportunity cost to Nigeria's economy due to poor quality electricity service exceeded $900 million (Nelson, 2008). This figure is probably much larger today since conditions in Nigeria have not improved considerably. Before exploring potential solutions to Nigeria's energy crisis, it is necessary to closely examine the energy production issues that have plagued Nigerian consumers. This section will first explore Nigeria's energy mix followed by the specifics of electricity accessibility issues, and then will delve into the political interactions with the energy sector, specifically with that of solar energy. Then, the authors will explore the possibility of renewable energy use, concluding with an in-depth look into the potential for solar energy. The authors argue that solar energy holds the greatest potential for addressing issues of electric accessibility, economic growth, and climate change mitigation techniques for Nigeria.

Energy Use in Nigeria

Crude Oil

The Nigerian economy is heavily dependent on its oil sector which accounts for 85% of government revenues and is the 2nd largest contributor to GDP following agriculture (Energy Information Agency (EIA)). Nigeria produces over 2.17 million barrels of oil per day (bbl/d) making it the largest producer of oil in Africa. The large majority of this oil is exported to other countries. Oil exports are approximately 1.9 million per day (EIA). In 2008, Nigeria consumed about 286,000 bbl/d (EIA) of oil. This accounted for nearly 53% of the energy consumption in the country (EIA). Although Nigeria has four refineries with a combined capacity of around 500,000 bbl/d, the country imports 85% of refined products (EIA). In 2009 the Nigerian National Petroleum Corporation reported that only one of these refineries remains operational, but it is running below capacity (EIA). The operation problems in these refineries are attributed to corruption, poor maintenance, theft, and fire. Many of these factors are recurring issues around production in the energy sector as a whole. Plans to privatize these refineries in order to increase investment and improve performance have been met with stiff opposition from government parties and workers unions. Current price subsidy schemes put in place by the government lead oil producers in Nigeria to sell overseas rather than to local refineries. Given the current reserves and rate of exploitation, the expected lifespan of Nigeria's crude is about 44 years (Ajoa et al. 2009). Oil consumption in the country is mainly used for automobiles, but the natural gas that is given off during the refining process is very important for the production of electricity.

Natural Gas

The next largest contributor to total energy consumption in Nigeria is natural gas. It makes up about 39% of energy consumption in the country. Nigeria has the largest natural gas reserve in Africa, but the country has limited infrastructure in place to develop the sector (IEA). With over 184 trillion cubic feet of proven natural gas, Nigeria is the seventh largest natural gas holder in the world (EIA). Most of the natural gas reserves are in the Nigerian delta. Gas discovery in Nigeria was incidental to oil exploration and production. In 2007 Nigeria produced 1.20 trillion cubic feet of natural gas while consuming 465 billion cubic feet of natural gas (EIA). Approximately 794 billion cubic feet of natural gas was exported (EIA). Issues with the production of natural gas center around the flaring of Nigeria's oil fields. Due to the lack of adequate infrastructure, refineries are unable to sufficiently capture the natural gas that is given off during the refining process. This gas instead burns up as flares. These oil fields often flare because they lack the infrastructure necessary to efficiently produce and market associated natural gas (EIA). Over 75% of the natural gas produced in the past has flared (Ajoa et al. 2009). Flaring was recently reduced to an annual rate of 36% as a result of strident efforts by the Nigerian government. Yet in 2007 Nigeria flared 593 Bcf of natural gas which cost the country US$ 1.46 in lost revenue (Ajoa et al. 2009).

About 80% of the natural gas that Nigeria produces is used domestically for electricity generation while the remaining is used mostly for other purposes in the industrial sector. A negligible amount of the natural gas is used for other purposes in households (Ajoa et al. 2009). With the necessary infrastructure for improved plants and pipelines in Nigeria, it is possible to convert more natural gas to electricity. The country is currently in the process of establishing infrastructure to better harness this energy. The government has also been working for several years to end natural gas flaring, but the deadline has been continuously pushed back. Nigerian policymakers recently planned to implement a Gas Master Plan that would promote new gas-fired power plants that would help reduce gas flaring and subsequently provide improved electricity generation (EIA). Security issues have also affected the production of natural gas in the Niger Delta (EIA). Given the current reserves and rate of exploitation, the expected lifespan of Nigeria's natural gas is about 88 years (Ajoa et al. 2009).

Hydro-Electric Power

Hydro-electric power makes up the remaining 7% of total energy consumption in Nigeria (EIA). It is estimated that 7,714 GWh of hydro-electric power is produced and consumed in the country (EIA). Hydropower systems rely on the potential energy differences between the levels of water and discharge tail water levels downstream (Ajoa et al. 2009). There are several problems associated with the production of hydro-electric power in Nigeria. Infrastructure in this sector is inadequate and in need of rehabilitation as well. The poor maintenance of the hydro-electric plants results in electricity output far below capacity. The overall hydropower resources potentially exploitable in Nigeria are over 11,000MW, while current production is slightly less than 2,000 MW (Ajoa et al. 2009 & IEA). Outputs from these plants are further hindered because production is highly oscillatory according to seasonal droughts. It has also been put forward that production has been hindered by climate change causing a continual loss of water (Darling et al. 2008). The two rivers that provide the majority of hydropower generation are the Niger and the Benue. These rivers pass through Niger and Cameron prior to entering Nigeria. Nigeria exports a portion of the energy generated by its hydro-plants to Niger in order to compensate the country for not installing their own dams on the rivers and taking away from potential production capacity. Electricity production within hydro-electricity is therefore limited without even considering the inefficiencies of the plants themselves.

Other Forms of Energy

Coal, nuclear, and renewable energy with the exception of biomass are currently not part of Nigeria's energy mix. Nigeria has a sizeable coal reserves of about 693 million tones, but production has not been at a substantial level since the early 1990s (Ajoa et al. 2009). The government is currently considering plans to increase coal production as a source of additional power generation (EIU). Nigeria is endowed with an abundant amount of renewable energy resources. The most significant renewable resources available are solar energy, biomass, wind, and hydropower. With the exception of hydropower the current exploitation and utilization of these resources is very low and largely limited to pilot and demonstration projects (Ajoa et al. 2009). The main constraints to mass diffusion of renewable energy technology in Nigeria are the absence of market and the lack of appropriate policy, regulatory, and institutional framework to stimulate demand and attract investors (Ajoa et al. 2009). The high initial upfront capital cost provides a barrier to the development of markets.

In rural areas a substantial amount of energy is provided by the burning of fuelwood (firewood). Fuelwood is a form of biomass that harnesses the fuel from wood for energy. This form of energy is often used for heating and cooking needs. A host of problems exist with the burning of firewood. The emissions given off from the burning of fuelwood is toxic, even more so when done in doors. The burning of fuelwood is also contributing to the already heavy deforestation of Nigeria caused by the growing timber industry. Due to the growing scarcity of wood a person on average has to spend 4-6 hours collecting enough wood for a single day's meal (Darling et al. 2008). This results in economic opportunity cost issues discussed later.

Electricity Accessibility Issues

Electric power is generated by both hydro electric power and thermal stations. The former uses water and the latter employs gas or steam. Large hydro accounts for 31.3% of grid electricity generation while natural gas accounts for the remaining 68.3% (Ajoa et al. 2009). While hydroelectric power is cheaper, the infrastructure required for dams and accompanying structures is more expensive. The thermal plants cost less to construct, but are more expensive to run due to the fact that the gas or coal used to generate the electricity is a waiting asset, whereas water is renewable (Olukoju 2004).

The history of electricity in Nigeria dates back to 1896 when electricity was first produced in Lagos, fifteen years after it was introduced in England (Ajoa et al. 2009). The development of electricity since then has been at a relatively slow rate. In 1950, Nigeria's legislative council transferred the care of electricity supply and development to a central body called the Electricity Corporation of Nigeria (ECN). There are a few other bodies that have licenses to produce electricity in some locations in Nigeria such as Native Authorities and

Nigeria Electricity Company. Nigeria Dams Authority (NDA) was established in 1962 and was responsible for the construction and maintenance of dams and other works on the Niger River. Energy produced by NDA was sold to the Electricity Corporation of Nigeria for distribution and sales at utility voltages. The National Electric Power Authority (NEPA) was established in 1972. It was a merger of ECN and NDA, and it was vested monopoly over generation, transmission, and distribution of electricity in Nigeria (Olukoju 2004).

For over 20 years prior to 1999, there was very little substantial investment for infrastructure development to the power sector (Ajoa et al. 2009). During the period new energy plants were not constructed and the existing plants were not properly maintained. The demand for electricity has always outstripped supply (Olukoju 20004). This disparity increased phenomenally with the increase in population and revenue during the oil boom in the 1970s (Olukoju 2004). The growth in per capita income during the period led to an increase in consumption of electrical and electronic appliances. This caused an increase in demand for electricity particularly in large urban centers like Lagos. The city consumes half of the total energy generated in the country (Olukoju 2004). The widening gap between demand and supply is reflected by the irregular power supply and frequent outages since the 1980s. In 2001 it was reported that installed capacity for electricity was around 5,600 MW while actual electricity generation was only at an average of 1,750 MW. Electricity demand during the time was over 6,000 MW (Ajoa et al. 2009).

Electricity generators are unable to produce at full capacity for several technical reasons. The electric energy supply efficiencies of existing thermal plants are as low as 12%. With modern technologies efficiency gains of up to 40% are attainable (Ajoa et al. 2009). There is also a considerable problem with substantial electricity losses during transmission and distribution. The unreliability and inefficiency of the power sector has been attributed to the following major acute factors (Ajoa et al. 2009):

I. Frequent breakdown of generating plants and equipment as a result of inadequate repairs and maintenance
II. Lack of foreign exchange to purchase needed spare parts on time
III. Obsolete transmission and distribution equipment, which frequently break down
IV. Lack of skilled manpower
V. Inadequacy of basic industries to service the power sector

The poor performance by NEPA has been attributed to several reasons as well. Its nature as a state monopoly is generally believed to stifle productivity, foster poor accountability, and preclude much needed investment (Olukoju 2004). Private sector participation can inject substantial capital and competition beneficial for incentivizing gains in efficiency into the sector. It is also believed that the energy sector in recent times has been under-funded (Olukoju 2004). It is unclear to what extent these claims are true. The institution has been accused of embezzlement in several occasions (Olukoju 2004). Another negative factor affecting NEPA's performance is frequent vandalizing of NEPA equipment by locals who sell the equipment for private gain. NEPA equipment was not replaced or maintained properly during a prolonged military rule of Nigeria that was characterized by lack of accountability and massive corruption (Olukoju 2004). Since NEPA has failed to provide a regular supply of electricity, locals jokingly interpret 'NEPA' to mean "Never Expect Power Always' (Olukoju 2004).

Decentralized Approach to Energy Accessibility

The concept of decentralization is one that has received attention in response to accessibility issues in rural areas of developing nations. What lies beneath this approach to energy provision is the fact that in many rural areas of developing nations, transmission of energy is very difficult. The geographic terrain and diffusion of communities makes transporting energy inefficient. Therefore, a centralized power source and grid system is not cost efficient. As a result many countries neglect to supply energy to such locales or when they do, the energy is unreliable. Nigeria is a prime example of this problem as much of the nation's population lives in rural areas that are characterized by varying geography (i.e. the labyrinthine water systems of the Niger Delta).

Decentralized electricity production involves the production of energy at or near the point of consumption and can entail both renewable and non-renewable energy sources that contribute to on-grid or off-grid energy systems (Akinbame 2001; Ajao, Ajimotokan et al. 2009). Small-scale, decentralized electric generation does not require the large initial capital investment that a large power supply would; therefore the ease of implementation is more readily possible in rural areas. As mentioned, decentralized electricity does not necessarily entail renewable energy, but is characterized by the nature of where the energy is produced. Such systems promote environmental sustainability, electric production for economic development, and create new jobs for local entrepreneurs who would install and service the systems (Ajao, Ajimotokan et al. 2009). The implementation of such systems in Nigeria is contingent upon having sufficient funds for their development and installation. The authors believe that the ability to attract foreign capital both through the privatization of the industry and foreign loans and aid is crucial to the accessibility to electricity in rural communities. Such systems would spur economic growth but also meet the growing concerns of economic growth, energy consumption, and climate change.

Economic Implications

Nigeria's economic expansion is held back by the continual under-performance of the country's energy sector. Its acute electricity problems are hindering the country's development notwithstanding the availability of vast natural resources in the country. Industrial growth has been stymied by the absence of a steady, reliable, and sufficient supply of electricity. As a result most industries are forced use expensive and environmentally unfriendly generators to sustain regular production (Barret 2008).

Nigerians rent or purchase power-generating plants of various sizes and descriptions (Olukoju 2004). They range from petrol-powered small sets to huge diesel-operated units installed in high rise buildings. The more affluent inhabitants acquire generators as a supplement to electricity supplied by NEPA. In the most affluent areas of Nigeria such as

Victoria Island and Ikoya, ownership of a diesel-powered generator is a regular fact of life (Olukoju 2004). In many residential parts of Lagos there are very few household without a stand-by generator. The cost of fueling the generators, aggravated by fuel shortages, and the general cost of maintenance is a heavy burden on even the most affluent residents (Olukoju 2004). Poorer residents are left to simply rely on very insufficient and dangerous sources of energy such as rechargeable lamps, hurricane lanterns, or candles.

Industries in Nigeria spend a large portion of their overhead costs on electric generation (Olukoju 2004). Large enterprises are able to survive because their profit margins can usually bear the costs. Small and medium scale enterprises are generally worse off due to the lack of economies of scale and adequate capital to bear high electric generation costs (Olukoju 2004). Many have gone bankrupt due to the heavy cost of generating electricity (Olukoju 2004). Many small service industries such as welders, panel-beaters, and barbers cannot afford to acquire electricity generating sets thus they are limited to the services that they can provide (Olukoju 2004). Consequently, the irregular power supply by NEPA has forced many of these small-scale service providers to diversify into other small-scale business that do not require electricity (Olukoju 2004).

It is also believed that the erratic power supply by NEPA causes an upsurge in crime (Olukoju 2004). Regular black-outs provide adequate cover for armed robbery, burglary, and vandalization of property (Olukoju 2004). Would be small scale entrepreneurs who are unemployed have high incentives to aid in robbery gangs. Most armed robbery suspects caught by the police have been unemployed or underemployed artisans (Olukoju 2004).

Poorer and rural residents also face more detrimental effects of the energy crisis. As stated earlier, rural residents are forced to rely on the burning of fuelwood for cooking and heating needs. As much as 10 to 12 hours a week per household may be spent on fuel collection during fuel shortage conditions (Aina 1998). This represents large opportunity costs. Increased time spent on firewood collection and cooking means women are left with less time for productive, domestic activities and income generating activities such as farming and food production and processing (Aina 1998). Poor families have to give valuable labor time to access available fuels and may even be forced to enter into exploitive wage labor relationships (Aina 1998).

A general overview of the main forms of energy used in rural areas of developing countries indicate that the general pattern during economic progress is to move from biofuels, and human and animal power, to a mix of traditional and modern fuels (Table 1, Barnes et al. 1996). This process is recognized as the movement up the “rural energy ladder”. This movement highlights the importance of enabling conditions for income growth. Increasing per capita income levels and increasing use of modern fuels are highly correlated (Figure 1, Barnes et al. 1996). Advances in technology and reduced costs of supplying modern fuels lower the income level at which a complete shift to modern fuels can be made (Barnes et al. 1996).

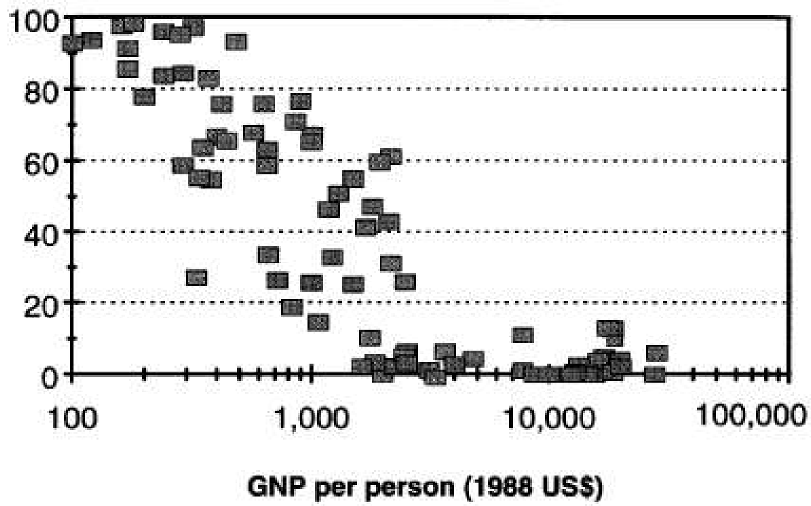

Figure 7: Percentage of Biomass in Total Energy Used. Traditional energy and GDP. Percent biomass use and GNP per person. (Barnes, et. al.)

End use	Income stage: Low	Income stage: Medium	Income stage: High
Household			
Cooking	Wood, residues, and dung	Wood, residues, dung, kerosene, and biogas	Wood, kerosene, biogas, LPG, and coal
Lighting	Candles and kerosene (sometimes none)	Candles, kerosene, and gasoline	Kerosene, electricity, and gasoline
Space heating	Wood, residues, and dung (often none)	Wood, residues, and dung	Wood, residues, dung, and coal
Other appliances	None	Electricity and storage cells	Electricity and storage cells
Agriculture			
Tilling	Hand	Animal	Animal, gasoline, and diesel (tractors and small power tillers)
Irrigation	Hand	Animal	Diesel and electricity
Postharvest processing	Hand	Animal	Diesel and electricity
Industry			
Milling and mechanical	Hand	Hand and animal	Hand, animal, diesel, and electricity
Process heat	Wood and residues	Coal, charcoal, wood, and residues	Coal, charcoal, kerosene, wood, and residues

Table 14: Rural energy use patterns in developing countries by end uses. (Barnes et. al.)

Environmental Implications

The wide residential and industrial usage of energy substitutes causes major environmental threats. In urban areas of Nigeria the boom in the sale and service of electricity generators since the 70s has caused a significant increase in the amount of carbon dioxide discharged in the atmosphere (Olukoju 2004). In the rural residential energy sector the poor management of wood resources during the collection of fuelwood has resulted in various ecological problems such as deforestation, erosion and, desertification (Aina 1998). In Nigeria deforestation is estimated to be at a rate of 400,000 hectares per annum, and dessert encroachment is estimated at 6 million hectares per annum (Aina 1998). Erosion has led to the loss of land in the coastal and marine environment at a rate of 25-30 meters per annum in Lagos (Aina 1998). The household itself is identified as a major contributor of CO_2 emissions in Nigeria. The World health Organization reported that a cook using fuelwood in the household can inhale an amount of benzopyrene equivalent to 20 packets of cigarettes a day (Aina 1998). Cases of chronic carbon monoxide poisoning have been reported.

The Politics of Energy in Nigeria

The electric energy sector of Nigeria is governed by the National Electric Power Authority (NEPA), which was established in 1972. NEPA acts as a government established monopoly on issues related to power generation, transmission, and distribution (Ikeme and Ebohon 2005). However, NEPA is largely an inefficient program which has struggled to properly fund and orchestrate the energy sector as a whole. This inefficiency and lack of capacity has led to the desire to privatize the industry, a shift that will be discussed more below.

As far as policy and energy is concerned, the most notable advancement by the Nigerian government was in 2003, when the Energy Commission of Nigeria (ECN), approved the National Energy Policy (NEP) that outlines the governments policies, strategies, and objectives in regard to energy use and development. While the authors here will not provide an analysis of the entire document, themes and initiatives that specifically relate to the role of solar energy and accessibility will be covered. These themes include the general philosophy of the NEP toward energy and economic growth, energy access, private sector involvement, and solar energy development. Addressing the political position and goals of the Nigerian government provides a framework for analyzing the future prospects and feasibility of solar energy as an important means to alleviate accessibility issues and instigate economic development and sustainability.

The NEP places a great amount of emphasis on the interaction between Nigeria's energy policy and economic advancement. In fact, the economic trajectory of Nigeria functions as a backdrop for many of the energy related policies and objectives. From an overall perspective, the NEP recognizes the need to utilize all forms of energy possible, especially in areas that do not have access to the energy grid, but will play increasingly large roles in the industrial sector of the country's economy. Further, they emphasize continued energy development to integrate sustainable philosophies of development. As stated in the NEP, Nigeria's energy policy needs to, "[P]romote the harnessing of all the viable energy resources so as to have an optimal energy mix, while ensuring sustainable and environmentally friendly energy practices" (Lukman 2003). The following are stated general objectives of the NEP. The continued reference to diversified and renewable energy use in regard to economic advancement and energy accessibility is of particular relevance to this project.

Objectives of the National Energy Policy

i. To ensure the development of the nation's energy resources, with diversified energy resources option, for the achievement of national energy security and an efficient energy delivery system with an optimal energy resource mix.
ii. To guarantee increased contribution of energy productive activities to national income.
iii. To guarantee adequate, reliable and sustainable supply of energy at appropriate costs and in an environmentally friendly manner, to the various sectors of the economy, for national development.
iv. To guarantee an efficient and cost effective consumption pattern of energy resources.
v. To accelerate the process of acquisition and diffusion of technology and managerial expertise in the energy sector and indigenous participation in energy sector industries, for stability and self-reliance.
vi. To promote increased investments and development of the energy sector industries with substantial private sector participation.
vii. To ensure a comprehensive, integrated and well informed energy sector plans and programmes for effective development.
viii. To foster international co-operation in energy trade and projects development in both the African region and the world at large.
ix. To successfully use the nation's abundant energy resources to promote international co-operation (Lukman 2003, 9)

Elsewhere in the document (39), the ECN pays more attention to the issue of accessibility both for industry and economic advancement as well as for rural areas that are not specifically linked to industry (though may in the future). In regard to industry, the NEP acknowledges that the supply of energy must be made available to meet the needs of all industrial activities in a way that is as environmentally sustainable as possible. They specifically address the concept of decentralization and local sourcing to meet these needs. The NEP states the goal of providing 75% of the population with electricity by 2020. Part of this initiative and goal realization will be achieved by diversifying the energy supply mix and encouraging off-grid generation of power in rural and isolated areas (Lukman 2003, 38).

In regard to realizing the goal of rural electrification, in March 2006, the government established the Rural Electrification Agency of Nigeria (REA). The goal of the REA is to expand rural and peri-urban access to electricity in a cost-effective manner, using both grid and off-grid options. Further, the underlying objectives of the REA are to improve the living conditions through energy access for agricultural, commercial, and domestic activities, raise the standard of living through improved electric security, and protect the nations' health and environment through reduction of energy related hazards. The REA has set forth specific strategies to meet these objectives which include expanding the main electricity grid of Nigeria, developing isolated and mini-grids, exploring renewable energy technologies, providing subsidies for access expansion rather than consumption, and establishing a Rural Electrification Fund (REF) that would secure funding from a variety of sources. The sources listed for this fund include local government budgets, tariffs on electric use, as well as donations and loans from international sources. Finally, a major push of the REA is the mobilization of capital for private-sector investment in the development of rural power accessibility (Nigeria 2009).

Inefficiency of NEPA has led to the emphasis for Nigeria to privatize the electric power industry (this shift received much attention in the NEP). The goal of this shift would be to stimulate investment and promote competition and efficiency of the power sector in order to meet social demands (Ikeme and Ebohon 2005). Historically, the energy sector has been relegated to the government's oversight. Yet, funding and management deficiencies have caused there to be more belief in private sector participation and investment in the energy sector. The ECN states that much of the shift will be developed through foreign direct investment, which they hope will better meet the crisis of technology development, energy access, and economic advancement (Lukman 2003, 38). If this stated objective does continue, the role of developed nations and multi-national corporations in Nigeria will greatly increase.

An important aspect of Nigeria's political stance on energy development resides in the fact that they are adherents to the Kyoto Protocol. The significance of this for this paper is that different initiatives of the Kyoto Protocol (Article 4 and 10) specifically address the transfer of environmentally sound technology and promotion of sustainable development practices from developed countries to developing countries. The practical fallout from these policies would be seen in the increased financing of technologies and capacity building for countries such as Nigeria. However, as Akinbame (2001) states, the actual transfer of such technologies has not been implemented and the future success of such transfers largely depends on the establishment of strong institutions in destination countries.

Solar Energy Policy

The potential for solar energy is abundant in Nigeria but has barely been pursued up until this point by the government. However, solar power has begun to receive more attention in Nigerian policy discussions. The NEP states that, "[W]hen the availability and environmental costs of the utilization of other forms of energy are considered, the competitiveness of solar energy in comparison with these other forms becomes very evident, particularly for low to medium power applications" (Lukman 2003, 28). Solar energy is split into both solar-thermal and PV, with the majority of the focus being on PV and its potential utilization in low to medium power applications (1-10 kW) in remote areas (i.e. refrigeration, communication stations). The use of PV could largely be accomplished through decentralized approaches that don't tie into the grid, but some instances could see PV systems feeding the national grid as well.

Acknowledging this potential, the NEP set forth the following policies, objectives, and strategies for solar energy use (Lukman 2003, 29).

Policies

i. The nation shall aggressively pursue the integration of solar energy into the nation's energy mix.
ii. The nation shall keep abreast of worldwide developments in solar energy technology.

Objectives

i. To develop the nation's capability in the utilization of solar energy.
ii. To use solar energy as a complementary energy resource in the rural and urban areas.
iii. To develop the market for solar energy technologies.
iv. To develop solar energy conversion technologies locally.

Strategies

i. Intensifying research and development in solar energy technology.
ii. Promoting training and manpower development.
iii. Providing adequate incentives to local manufacturers for the production of solar energy systems.
iv. Providing adequate incentives to suppliers of solar energy products and services.
v. Introducing measures to support the local solar energy industry.
vi. Setting up extension programmes to introduce solar technology into the energy mix.
vii. Providing fiscal incentives for the installation of solar energy systems.
viii. Setting up and maintaining a comprehensive information system on available solar energy resources and technologies.

In conclusion, the NEP provides a very large framework for looking at the use of solar energy in Nigeria and agencies such as the REA further promote the use of renewable energy. The fact that they set forth many objectives and strategies for the implementation of solar technologies creates an atmosphere that at least appears not to inhibit the exploration of solar energy use. By addressing both the need to use sustainable energy sources for economic growth and the current and future issues Nigeria has with accessibility, the government has acknowledged the main issues that this paper seeks to address. Combined with the ramifications and possibilities of Nigeria's adherence to the Kyoto Protocol as well as the shift from public to private governance of the energy sector, the possibility for international and corporate implementation of solar technologies in marginalized areas holds great potential. Unfortunately, as will be elaborated upon below, this potential has not been realized as the government has been relatively stagnant on the actual implementation of solar energy systems.

Political and Social Barriers to the Use of Solar Energy in Nigeria

In lieu of the research presented above, the fact that solar energy has not been readily implemented in Nigeria suggests that there are barriers to a more radical adoption of solar energy systems in the country. The authors propose that this occurrence comes from a number of arenas.

While the government has addressed solar energy usage in policy documents such as the NEP and in the establishment of agencies like the REA, action toward installing solar systems has been minimal (Chineke and Okoro 2010). The lack of mobilization of the government to fund or provide incentives for the development and installation of such systems has not aligned with the stated goals of their policy. Certainly the full extent of this lack of mobilization is not solely located within the Nigerian government, but international cooperation has not extended to the point where solar energy can be developed either. The provision of the United Nations Framework Convention on Climate Change mandates Annex 1 Parties to transfer environmentally sound technology and support to developing countries; an initiative that has not been implemented to any meaningful or significant extent (Akinbame 2001; Sambo 2008).

Another factor that may play into the ineffective establishment of solar energy systems is lack of public awareness and support. Awareness, especially in rural areas, for renewable energy is low, which inhibits the possibility that the public will push for the government to develop and install renewable energy systems (Akinbame 2001). In addition, many of the rural communities that do not have access to electricity reside in the Niger Delta, which is rich with crude oil. This may create a perception of fossil fuel abundance and further the lack of perceived need for renewables.

Current Renewable Energy Usage in Nigeria

Nigeria, unlike many developing nations, is fortunate in that it is abundant in energy resources. The country is well known for its petroleum, natural gas, tar, and coal deposits, and with such vast natural energy resources, it is not surprising that the country also consumes a large amount of liquefied petroleum, diesel, fuel and gas oil. However, it is also rich in renewable energy sources such as solar, hydro, biomass, and wind energy (Kevelaitis 2008), which, if fully harnessed, could potentially solve Nigeria's energy accessibility needs. Renewable energy alternatives are particularly attractive because, in addition to being able to address Nigeria's own problems of energy accessibility, it is clear that with international concerns over global warming (particularly as it will disproportionately affect developing countries such as Nigeria) and the inevitable depletion of petroleum reserves, the country needs to thoroughly explore it's renewable resources.

Fortunately, there are several types of renewable energy available in Nigeria for the country to take advantage of to address these issues. These include biomass, hydropower, wind power and solar power. While some of these are currently in use, they are not universal in their effectiveness or potential. It is our assertion that because all alternative energies are not created equal, that of the types of renewable energy that are available in Nigeria, solar power has the most potential to provide affordable electricity to the country, particularly to those living off the power grid in the rural regions. Thus, solar technology should be developed and implemented on a larger scale in the country. However, it is necessary to perform an analysis of each type of renewable energy option available to Nigeria to make such a claim viable.

Biomass

At present, one of the most widely used types of renewable energy that is available in Nigeria is biomass. Biomass includes a broad spectrum of energy-producing products, including fuel wood, saw dust and agricultural residue and municipal waste. While biomass agents are currently used throughout Nigeria, fuel wood is the most prolific. Its heavy usage is evidenced by the fact that between the years of 1989 and 2000 fuel wood and charcoal constituted between 32% and 40% of energy consumption in the country (Kevelaitis 2008). However, while fuel wood is an attractive source of renewable energy as it is easily acquired and less hazardous to the environment than burning coal or processing petroleum, its widespread use has led to problems of deforestation. According to current calculations, approximately 350,000 hectares of natural vegetation and forest are destroyed annually, and the deforestation rate is expected to increase alongside the increasing demand for energy (Sambo 2009). Therefore, while fuel wood is more beneficial to the atmosphere than fossil fuels, its use in fact depletes vital resources. Thus, it is necessary to examine other sources of renewable energy.

Hydropower and Wind Power

Other sources of biomass include hydropower, which is also relatively easily accessible, and whose utilization does not harm the environment. Hydropower projects can be divided into small and large-scale developments, both of which are currently used in Nigeria. The small-scale developments (SHP) have much renewable energy potential, and are currently used on a relatively large-scale as a result of the network of rivers and waterfalls that run throughout the country. It can indeed be an affordable option to provide electricity to those who live off the grid, and is therefore not surprisingly beginning to appear more and more in rural areas. SHP's exist all over Nigeria, with an estimated capacity of 3,500 MW (Sambo 2009). In fact:

"The current initiative by the Nigerian Energy Commission and the Solar Energy Society of Nigeria towards developing and implementing solar power systems to meet the needs of rural villages and communities not currently served by the NEPA power grid is thus a step in the right direction. This focus on renewable should also exploit Nigeria's massive hydropower potential which is estimated to be 36,000GWh/yr (IEA 2001). This should be developed as relatively low cost small-scale hydro-electric sites as opposed to the environmentally destructive large-scale projects" (Ikema 2005, 1215).

While SHP's are in a state of relative infancy, large-scale hydro is also used extensively, and contributes 31% of the grid energy. However, as previously mentioned large-scale productions also have environmental pitfalls. Both biomass and hydropower have been exploited to varying levels of success in the country, though Nigeria has yet to begin to harness the potential of wind power, due to meteorological and technical restraints.

Solar Power

There are a variety of renewable energy alternatives available to Nigerians; however, the most attractive option at this point in time is solar energy. This is because implementing a large-scale solar power project is technologically feasible and cost-effective. Currently, solar power is not used on a widespread basis in Nigeria, however it has almost unlimited potential and would greatly ease Nigeria's energy burdens.

Why Solar?

Solar Power can be harnessed to provide Nigeria with almost unlimited energy because Nigeria is located in a high sunshine belt with enormous energy potential. More specifically, Nigeria falls between latitude 4 – 14° North of the equator. This is significant as studies that have been conducted on the solar radiation pattern in the country have reported that, as a tropical country, Nigeria is the recipient of as much as 20 MJ/M^2 per day of solar insulation (depending on the time of the year and the location). In fact, the Nigerian Federal Ministry of Science and Technology "estimates that the total annual energy consumption of about 21 x 109 kWh could be made by converting only 0.1% of the total solar radiation incident on the country at a conversion efficiency of 1%" (Offiong 2003). It is therefore not surprising that solar thermal applications are already developed in the country, and that the country is technologically capable of developing the applications further (though considerations of technology are integral and they will be discussed further below).

Technical Aspects

It should be noted that our analysis supporting the use of solar energy in Nigeria assumes a Photovoltaics (PV) system. A PV systems functions by essentially converting sunlight directly into electricity. Specifically, the:

"[P]hotons in sunlight interact with the outermost electrons of an atom. Photons striking the atoms of a semi-conducting solar cell free it's electrons, creating an electric current. Current conversion efficiencies have surpassed 30% in the laboratory, and 15% in large-scale production"(SELF 2007).

There are two principle types of silicon cells that are available on the market: crystalline and thin-film. This is noteworthy because modules from "crystalline cells have a lifetime of over twenty years. Thin-film modules will last at least ten years" (SELF 2007). Other PV technologies being utilized are Gallium-Arsenide or Cadmium Telluride. However, while they are highly efficient, they are presently more expensive.

Given current technological considerations, a small scale PV system requires several key components: a module, a battery, a charge controller, lights and a wiring and mounting system. At present, solar modules are attached to either a rooftop or a pole. The battery, which is an electrochemical storage battery, stores the electricity converted by the solar module. Batteries are usually 12-volt, which range in capacity from 20-100 Amp-Hours. The best type of battery is a deep-cycle battery, which, sealed and unsealed, can last 7-10 years. The charge controller, which is used to control the flow of electricity between the module and the battery, prevents battery damage by ensuring that the battery is operating within normal levels. (SELF 2007)

Cost-Benefit Analysis of Solar Power for Nigeria

It is our belief that solar power is the most efficient option for Nigeria in its efforts to pursue renewable energy alternatives, however there remain several roadblocks, the most prominent of which is economic. The main question here is how can Nigeria provide energy to the countries poorest populations who have no resources with which to pay for the energy? This requires conducting a cost-benefit analysis of implementing a large-scale solar power project in the country.

Cost Analysis

This cost analysis will attempt to pinpoint the most basic cost of providing solar energy to parts of Nigeria. To wit, according to the 2009 CIA Fact book the current population in Nigeria is 149,229,090. Our current assumption is that solar energy needs to be provided to 47% of the Nigerian population (See Benefit Analysis), meaning that solar energy would need to be provided for 149,229,090 * .47 = 70,137,672.3 citizens. Furthermore, as will be discussed more explicitly in the *Further Economic Assessment* section, it costs approximately 1.5 Million Nigerian Naira (about 10,117.5 USD) to provide solar energy to each rural Nigerian household.

Keeping these factors in mind, we know that because the population in Nigeria is almost 150 million, and that we are aiming to provide electricity to 47 % of the country, or 70,147,672.3 citizens, and that the average household size is 6.84, that providing solar power costs approximately 10,117.5 USD per house, or 1479.17 USD per person.

Benefit Analysis

This simple benefit analysis attempts to take account for the real economic benefit of an increase in GDP per capita caused by the implementation of solar power in Nigeria. We are assuming that GDP per capita will increase with the implementation of solar power in areas where there is not enough energy to conduct business activity that requires electricity. Results show that increasing per capita income levels and increasing use of modern fuels are highly correlated (*Figure 7*, Barnes et al. 1996). With an adequate supply of electricity residents in these areas can increase their marginal productivity of labor and overall output. For example a farm that relies on electric powered equipment has more marginal output that a farm that relies mainly on manual labor.

Since less than 15% of rural areas currently have electricity in Nigeria, we analyzed the benefit of implementing solar energy in rural areas. This is sufficient for analyzing the effects of implementing solar power since most industries in rural areas of Nigeria solely rely on manual labor. It is also assumed that solar power will be implemented in two thirds of the rural population after 3 years. Rural areas make up roughly 70% of the population. Therefore our analysis is analyzing the economic affect of solar power on roughly 47% of the population.

We assume the life of a solar power unit is estimated to be about 25 years. We estimated current GDP per capita growth rate at about 5% following 2010. This is analogous to estimates made by the IMF (IMF). We then assumed GDP per capita would grow by 7%, 8%, and 10% in the downside case, base case, and upside case respectively for the 47% of the population where solar power is used. We calculated the new annual GDP per capita with solar power with the following formula:

[47% * (new growth rate) *(Old GDP per capita)] + [53% * (old growth rate) * (Old GDP per capita)] = New GDP per capita for given year

We calculated the present value of the gain in GDP per capita with an estimated real interest rate of 8%. Nigeria's MRR (rediscount rate) on Nov 27, 2009 is 16.5% (NGEX). The MRR is the official interest rate of the Central Bank of Nigeria (CBN). It anchors all other interest rates of the money market and the economy (CBN 2006). The inflation rate for 2010 in Nigeria is estimated by the IMF to be 8.5%. We calculated the real interest rate by taking the difference between MRR and inflation.

The difference between new GDP per capita and old GDP per capita for a given year is the benefit of solar power on the economy for a given year. The present values of these benefits for 25 years are $162.88, $244.73, and $408.42 per capita for the downside case, base case, and upside case respectively. The results can be seen in the model in the appendix.

Conclusion

Thus it appears that the present value of implementing solar power is equal to $408.42 - $1479.17 = -$1070 in an upside case, so our value here is negative. However, as mentioned this is a present value, and does not take into account the life expectancy and minimal maintenance cost of the solar modules, or other externalities not included in the model. As a result, it is not surprising to see entrepreneurs and foreign government beginning to heavily invest in solar energy in Nigeria.

Further Economic Assessment

Despite the negative present value of our Cost-Benefit analysis, the solar method of providing electricity to homes both on and off the grid is in fact far more effective than the current grid system. At present, "it costs about 150 million naira (around 1.2 million dollars) to connect each village to the national grid, while the solar energy project costs only about 10 million naira (around 83,000 dollars) per village" (SELF 2007). The success and economic viability of delving into such a solar project is evidenced by the fact that a project begun in 2002 by the Nigerian government, through the assistance of the Japanese government, has "lit 200 rural communities in Imo, Ondo and Jigawa states as well as in Abuja, the nation's capital" (SELF 2007). This is encouraging for economists for several reasons; it shows the economic effectiveness of pursuing solar in general, and it demonstrates the ability to attract foreign capital with such an investment.

This type of energy is an attractive investment not only for foreign governments and investors, but for local ones as well. In fact, in the past decade "several state governments, especially in the Northern states, have made some efforts to electrify parts of their rural communities with solar energy projects with counterpart funding"(SELF 2007). To this point:

"In 2001, Solar Electric Light Fund (SELF), an NGO based in USA, and the Jigawa State Government initiated a proposal to bring solar-generated electricity (PV) to power essential services in three villages of the state, with funding arrangement by United States government through USAID and Department of Energy (60 percent) and Jigawa State government (40 percent)" (Self).

While it is true that foreign and local investors have shown strong interest in investing in Nigeria's solar future, their investments must prove to be economically viable. This depends largely on the size of the solar power system, which will inevitably determine the system's fuel requirements, which is important for the evaluation of the photovoltaic solar powered system as a whole.

The first stage in conducting an economic analysis of potentially installing a PV system in a village, or even a single home, requires assessing the average electricity requirement for the typical Nigerian household combined with the cost of the PV system itself, as described in the Technological Aspects section. The average electricity consumption of a Nigerian household has been assessed in previous studies, and has been found that the size of "the generator required is a 1.5kw Engine since the total load is only 0.5kw and the average power requirement is 1.53kwh/day (approximately 1.6kwn/day) assuming each equipment is operated for 3h/day" (Offiong 2003). Furthermore:

"The cost of the diesel engine to run the generator has been estimated at N160,000.00 and maintenance cost are estimated at 25% of capital cost every year. Further studies have shown that 5 liters of fuel daily would be required to deliver the estimate 1.6kwh. It has been assessed that "with diesel cost at N35 per liter (realistic price instead of government fixed price) the total cost of fuel can be put at N63, 875 per annum" (Offiong 2003, 40).

The life expectancy of these diesel generators has been assessed as lasting ten years. It is problematic that the majority of the nation's homes factories "depend on generators for their main sources of power supply and this… has increased the cost of manufactured goods which is passed on to the consumer." (Olori 2006) This naturally has had a negative effect on the competitiveness of local products on the local and global market.

This only serves to heighten the need for an alternative, more cost effective, source of energy. Therefore, to determine the cost of a solar photovoltaic system that could be less expensive than generators, the photovoltaic module size must be estimated. In previous studies the PV module was estimated at 200-peak watt, requiring a total of 2 square meter PV modules of 100-peak watt per square meter are to be used. Also in need of consideration is battery storage capacity, and the market survey of battery data the battery storage capacity has been estimated at 2.5kwh. Therefore:

"The total costs of the required modules and inverters (output 230V, 50Hz) are N995, 000.00 from market studies. Installation costs and spares including battery replacement twice during the photovoltaic life span is estimated at N505, 000.00. The total comes to N1.5 million. With any photovoltaic system there is no fuel cost, maintenance cost is negligible, and the life expectancy of the system is 30 years" (Offiong 2003, 40).

Experts have concluded that "solar energy technology is less expensive than electricity generated by the new Power Holding Company of Nigeria (PHCN) that replaced the National Electric Power Authority (NEPA)" (Olori 2006) In addition to direct costs, it is clear that a Nigerian economy that relies firmly on oil and generators is at an economic disadvantage for additional reasons mentioned above.

Because studies have recently shown generators to be less effective than solar power, an effort to combat such economic disadvantages has begun and plans are currently underway to establish a solar energy training facility in Nigeria (Orakpo 2009). This is important for the Nigerian economy because, of among all types of renewable energy, "solar is the one that … can bring jobs and export earnings as well" (Orakpo 2009). For example, a "12.5mw solar manufacturing line which would create about 200 local jobs for the area, but most importantly, create exporting facilities to be able to export solar panels to neighboring African countries" (Orakpo 2009).

From these findings we believe it is evident that solar energy is an attractive solution to Nigeria's ever-growing energy needs. Not only is it more environmentally friendly and potentially much less corruptive than the nation's oil industry, but in fact given current costs it is cheaper than the nation's grid system, and the development of a solar power energy industry would both create jobs for those in the industry, and would allow the recipients of solar power a better opportunity to contribute to the local, national and international economy and bolster the country's GDP.

Recommendations for Nigeria

While the authors' opinions are strewn throughout the previous sections, the following is a synthesis of the authors' recommendations gathered from this study. The authors believe that the Nigerian government, local communities, international actors, and private entities should begin implementing a dramatic focus on solar energy investments in Nigeria. The benefits include, but are not limited to, the following:

i. Ameliorating energy accessibility issues, especially in rural areas that either have poor or no accessibility to the national power grid.
ii. Facilitating economic growth and alleviating poverty by opening the possibility for new economic ventures (through accessibility to energy).
iii. Providing electric support for human and health services in rural areas.
iv. Insuring sustainability of the localized environment (i.e. protecting the forests from being cleared for fuelwood use and providing alternatives to extractive fossil fuel resource activities)
v. Limiting greenhouse gas emissions that would undoubtedly increase if Nigeria's economic growth is dependent upon fossil fuel consumption.

The realization of the previously stated benefits is contingent upon proper implementation of solar energy systems. This is where the greatest challenge lies for Nigeria, both the public and private spheres. However, the authors do not believe that implementing solar energy on a large scale is unfeasible. Taking into consideration the economic analysis previously discussed as well as Nigeria's current portfolio and policy stances, the authors provide the following recommendations:

i. Privatizing some of the nations' energy-related functions. Delegating research and development to international or domestic markets will greatly enhance the possibility of solar technology diffusing in Nigeria. Further, the transmission of electricity itself can be more effectively done through private companies.
ii. Focusing on the concept of decentralization. The government (or private entities) need not continue to produce electricity at a central location and use methods of distribution that use inefficient and long channels of electricity transmission. For the reasons previously mentioned, government and private energy generation should be more focused on a community-based paradigm that also provides for local control of the source of energy.
iii. Focusing on the concept of decentralization. The government (or private entities) need not continue to produce electricity at a central location and use methods of distribution that use inefficient and long channels of electricity transmission. For the reasons previously mentioned, government and private energy generation should be more focused on a community-based paradigm that also provides for local control of the source of energy.
iv. Delegating time and money into revamping the older and inefficient energy infrastructure. In places where there is a centralized method of electricity diffusion and transmission, the power grid should be made more efficient.
v. Providing subsidies for renewable energy production. The government should reallocate funds to provide incentives for technological development and installation of such in rural as well as urban areas.
vi. Attracting foreign direct investment (both from private companies and partnering nations) for energy infrastructure and development. The international community should seize an opportunity to help an emerging economy become sustainable in its energy use and private firms can see this as an altruistic and profitable investment opportunity.
vii. Actualizing rhetorical and/or generalized statements regarding renewable energy in government established codes and standards for energy portfolios and use.
viii. Establishing public awareness campaigns that address issues of the costs, benefits, and reasonability of solar energy.

Conclusion: The Role of Renewable Energy in Developing Countries

The scope of the preceding project was to look at economic growth and renewable energy in developing countries. The rationale behind this study was two-fold. First, the authors see energy accessibility in developing countries as playing a crucial role in the economic growth of communities, which can contribute to poverty alleviation, provision of basic human services, and overall human well-being. Yet, as this growth occurs at a growing rate across the globe, the amount of people using electricity and energy will greatly increase. If energy production to meet the demands of such areas of growth is continued to be met with forms of energy that emit large amounts of GHGs, the negative patterns of climate change could become uncontrollable. Therefore, the authors here argue for extensive implementation of the use of renewable energy to meet the accessibility issues and economic growth addressed above.

The purpose of a comparative study was to not only provide insight into issues of energy accessibility, economic growth, and renewable energy in both Nigeria and India, but to synthesize common problems and solutions found in both cases in order to add insight for future policy and academic work that addresses renewable energy in developing nations. The cases presented here show that there may not be one prescriptive approach for implementing renewable energy systems in developing (or developed) nations. Differences in policy approaches, location on the development continuum, availability of distinct natural resources, and unique energy accessibility concerns are just some of the concepts that contribute to the different problems and solutions that face each nation. Despite these differences, there are some similarities between the two cases that deserve attention. While case-specific insights and recommendations can be found in the individual sections included above, the following are common themes the authors found in both case studies, which have the potential of framing future debates and policies regarding renewable energy in other areas of the globe as well.

Both countries showed to have great amount of resources for renewable energy use that were significantly unused. This may be due to a variety of factors that include lack of incentives to explore the use of such resources, inefficient technologies to develop them, lack of awareness for the benefits of renewable energy, dependency on other forms of energy, and insufficient funds to harness such energies. To help ameliorate this lack of development, home and international governments need to provide incentive for renewable energy development and technology diffusion, the public needs to be aware of such technologies and push policy makers for funding, and new cost-efficient technologies need to be developed and delivered. With that being said, in each case studied above, there was a certain type of renewable energy that was found to work best for the context. This evidence for country-specific contextualization of renewable energy implementation implores policy makers and entrepreneurs to conduct extensive research into the actual resources in specific areas and make informed decisions from such studies.

Lack of accessibility to energy was also found to be prevalent in both cases. While differing in nature, both cases showed that a lack of proper energy supply can inhibit economic growth. Renewable energy, whether it be in the form of a decentralized model or as a form of grid contribution, is thought to effectively help address the accessibility issues as well as provide for sustained economic growth. Again, while the issues of accessibility differ between Nigeria and India, both studies do lead to conclusive evidence that supports some sort of decentralized approach of energy generation for rural areas. Such systems can find a middle-ground between individualized forms of production and large-scale grid provision, both of which can be inefficient for rural communities.

The analyses of both countries also show that establishing renewable energy systems will have some fairly capital intensive up-front costs. While these costs may inhibit implementation, the authors argue that they have long-term positive effects not only on accessibility, but in turn, economic growth as well as climate change mitigation. Due to this barrier to entry, governments need to be open and willing to attract private investment in technology development and diffusion, as well as electricity production and transmission.

While these are not the only issues that face developing nations and the implementation of renewable energy systems in such places, the cases here support the imperative for developing countries to continue to adopt renewable energy portfolios as ways to address socio-economic and environmental concerns. The actualization of these initiatives will take the cooperation of governments and private industry, scientists and policy makers, and local participation and the international community. The research presented here is a piece of the agenda that seeks to uncover the possibility for renewable energy in developing countries; an agenda that requires further critical thinking and implementation.

Appendix

Upside Case

	Current Growth	Current GPD Per Cap	% Pop Using Solar	% Pop Not Solar	Expected Growth	Old Growth	New GDP Per Cap	Benefit	PV Benefit		
2009		$ 1,089.30	47%	53%	NA	NA	NA	NA	NA	MPR	0.165
2010	9.32%	$ 1,190.86	47%	53%	NA	NA	NA	NA	NA	Inflatiion	0.085
2011	4.49%	$ 1,244.37	47%	53%	NA	NA	NA	NA	NA	Interest rate	0.08
2012	4.93%	$ 1,305.76	47%	53%	NA	NA	NA	NA	NA		
2013	5.29%	$ 1,374.84	47%	53%	10.29%	5.29%	$ 1,405.31	$ 30.47	$ 22.39		
2014	5.09%	$ 1,444.80	47%	53%	10.09%	5.09%	$ 1,476.88	$ 32.08	$ 21.83		
2015	5.00%	$ 1,518.33	47%	53%	10.00%	5.00%	$ 1,550.76	$ 32.43	$ 20.44		
2016	5.00%	$ 1,594.24	47%	53%	10.00%	5.00%	$ 1,629.67	$ 35.43	$ 20.67		
2017	5.00%	$ 1,673.95	47%	53%	10.00%	5.00%	$ 1,711.15	$ 37.20	$ 20.10		
2018	5.00%	$ 1,757.65	47%	53%	10.00%	5.00%	$ 1,796.71	$ 39.06	$ 19.54		
2019	5.00%	$ 1,845.53	47%	53%	10.00%	5.00%	$ 1,886.55	$ 41.01	$ 19.00		
2020	5.00%	$ 1,937.81	47%	53%	10.00%	5.00%	$ 1,980.87	$ 43.06	$ 18.47		
2021	5.00%	$ 2,034.70	47%	53%	10.00%	5.00%	$ 2,079.92	$ 45.22	$ 17.96		
2022	5.00%	$ 2,136.44	47%	53%	10.00%	5.00%	$ 2,183.91	$ 47.48	$ 17.46		
2023	5.00%	$ 2,243.26	47%	53%	10.00%	5.00%	$ 2,293.11	$ 49.85	$ 16.97		
2024	5.00%	$ 2,355.42	47%	53%	10.00%	5.00%	$ 2,407.76	$ 52.34	$ 16.50		
2025	5.00%	$ 2,473.19	47%	53%	10.00%	5.00%	$ 2,528.15	$ 54.96	$ 16.04		
2026	5.00%	$ 2,596.85	47%	53%	10.00%	5.00%	$ 2,654.56	$ 57.71	$ 15.60		
2027	5.00%	$ 2,726.69	47%	53%	10.00%	5.00%	$ 2,787.29	$ 60.59	$ 15.16		
2028	5.00%	$ 2,863.03	47%	53%	10.00%	5.00%	$ 2,926.65	$ 63.62	$ 14.74		
2029	5.00%	$ 3,006.18	47%	53%	10.00%	5.00%	$ 3,072.98	$ 66.80	$ 14.33		
2030	5.00%	$ 3,156.49	47%	53%	10.00%	5.00%	$ 3,226.63	$ 70.14	$ 13.93		
2031	5.00%	$ 3,314.31	47%	53%	10.00%	5.00%	$ 3,387.96	$ 73.65	$ 13.55		
2032	5.00%	$ 3,480.03	47%	53%	10.00%	5.00%	$ 3,557.36	$ 77.33	$ 13.17		
2033	5.00%	$ 3,654.03	47%	53%	10.00%	5.00%	$ 3,735.23	$ 81.20	$ 12.81		
2034	5.00%	$ 3,836.73	47%	53%	10.00%	5.00%	$ 3,921.99	$ 85.26	$ 12.45		
2035	5.00%	$ 4,028.57	47%	53%	10.00%	5.00%	$ 4,118.09	$ 89.52	$ 12.10		
2036	5.00%	$ 4,230.00	47%	53%	10.00%	5.00%	$ 4,324.00	$ 94.00	$ 11.77		
2037	5.00%	$ 4,441.50	47%	53%	10.00%	5.00%	$ 4,540.20	$ 98.70	$ 11.44		
Total per Capita									**$ 408.42**		

Base Case

	Current Growth	Current GPD Per Cap	% Pop Using Solar	% Pop Not Solar	Expected Growth	Old Growth	New GDP Per Cap	Benefit	PV Benefit		
2009		$ 1,089.30	47%	53%	NA	NA	NA	NA	NA	MRR	0.165
2010	9.32%	$ 1,190.86	47%	53%	NA	NA	NA	NA	NA	Inflatiion	0.085
2011	4.49%	$ 1,244.37	47%	53%	NA	NA	NA	NA	NA	Interest rate	0.08
2012	4.93%	$ 1,305.76	47%	53%	NA	NA	NA	NA	NA		
2013	5.29%	$ 1,374.84	47%	53%	8.29%	5.29%	$ 1,393.12	$ 18.28	$ 13.44		
2014	5.09%	$ 1,444.80	47%	53%	8.09%	5.09%	$ 1,464.05	$ 19.25	$ 13.10		
2015	5.00%	$ 1,518.33	47%	53%	8.00%	5.00%	$ 1,537.27	$ 18.95	$ 11.94		
2016	5.00%	$ 1,594.24	47%	53%	8.00%	5.00%	$ 1,615.50	$ 21.26	$ 12.40		
2017	5.00%	$ 1,673.95	47%	53%	8.00%	5.00%	$ 1,696.27	$ 22.32	$ 12.06		
2018	5.00%	$ 1,757.65	47%	53%	8.00%	5.00%	$ 1,781.09	$ 23.44	$ 11.72		
2019	5.00%	$ 1,845.53	47%	53%	8.00%	5.00%	$ 1,870.14	$ 24.61	$ 11.40		
2020	5.00%	$ 1,937.81	47%	53%	8.00%	5.00%	$ 1,963.65	$ 25.84	$ 11.08		
2021	5.00%	$ 2,034.70	47%	53%	8.00%	5.00%	$ 2,061.83	$ 27.13	$ 10.77		
2022	5.00%	$ 2,136.44	47%	53%	8.00%	5.00%	$ 2,164.92	$ 28.49	$ 10.47		
2023	5.00%	$ 2,243.26	47%	53%	8.00%	5.00%	$ 2,273.17	$ 29.91	$ 10.18		
2024	5.00%	$ 2,355.42	47%	53%	8.00%	5.00%	$ 2,386.83	$ 31.41	$ 9.90		
2025	5.00%	$ 2,473.19	47%	53%	8.00%	5.00%	$ 2,506.17	$ 32.98	$ 9.63		
2026	5.00%	$ 2,596.85	47%	53%	8.00%	5.00%	$ 2,631.48	$ 34.62	$ 9.36		
2027	5.00%	$ 2,726.69	47%	53%	8.00%	5.00%	$ 2,763.05	$ 36.36	$ 9.10		
2028	5.00%	$ 2,863.03	47%	53%	8.00%	5.00%	$ 2,901.20	$ 38.17	$ 8.85		
2029	5.00%	$ 3,006.18	47%	53%	8.00%	5.00%	$ 3,046.26	$ 40.08	$ 8.60		
2030	5.00%	$ 3,156.49	47%	53%	8.00%	5.00%	$ 3,198.58	$ 42.09	$ 8.36		
2031	5.00%	$ 3,314.31	47%	53%	8.00%	5.00%	$ 3,358.50	$ 44.19	$ 8.13		
2032	5.00%	$ 3,480.03	47%	53%	8.00%	5.00%	$ 3,526.43	$ 46.40	$ 7.90		
2033	5.00%	$ 3,654.03	47%	53%	8.00%	5.00%	$ 3,702.75	$ 48.72	$ 7.68		
2034	5.00%	$ 3,836.73	47%	53%	8.00%	5.00%	$ 3,887.89	$ 51.16	$ 7.47		
2035	5.00%	$ 4,028.57	47%	53%	8.00%	5.00%	$ 4,082.28	$ 53.71	$ 7.26		
2036	5.00%	$ 4,230.00	47%	53%	8.00%	5.00%	$ 4,286.40	$ 56.40	$ 7.06		
2037	5.00%	$ 4,441.50	47%	53%	8.00%	5.00%	$ 4,500.72	$ 59.22	$ 6.86		
Total per Capita									**$ 244.73**		

Downside Case

	Current Growth	Current GPD Per Cap	% Pop Using Solar	% Pop Not Solar	Expected Growth	Old Growth	New GDP Per Cap	Benefit	PV Benefit
2009		$ 1,089.30	47%	53%	NA	NA	NA	NA	NA
2010	9.32%	$ 1,190.86	47%	53%	NA	NA	NA	NA	NA
2011	4.49%	$ 1,244.37	47%	53%	NA	NA	NA	NA	NA
2012	4.93%	$ 1,305.76	47%	53%	NA	NA	NA	NA	NA
2013	5.29%	$ 1,374.84	47%	53%	7.29%	5.29%	$ 1,387.03	$ 12.19	$ 8.96
2014	5.09%	$ 1,444.80	47%	53%	7.09%	5.09%	$ 1,457.63	$ 12.83	$ 8.73
2015	5.00%	$ 1,518.33	47%	53%	7.00%	5.00%	$ 1,530.53	$ 12.20	$ 7.69
2016	5.00%	$ 1,594.24	47%	53%	7.00%	5.00%	$ 1,608.41	$ 14.17	$ 8.27
2017	5.00%	$ 1,673.95	47%	53%	7.00%	5.00%	$ 1,688.83	$ 14.88	$ 8.04
2018	5.00%	$ 1,757.65	47%	53%	7.00%	5.00%	$ 1,773.27	$ 15.62	$ 7.82
2019	5.00%	$ 1,845.53	47%	53%	7.00%	5.00%	$ 1,861.94	$ 16.40	$ 7.60
2020	5.00%	$ 1,937.81	47%	53%	7.00%	5.00%	$ 1,955.04	$ 17.22	$ 7.39
2021	5.00%	$ 2,034.70	47%	53%	7.00%	5.00%	$ 2,052.79	$ 18.09	$ 7.18
2022	5.00%	$ 2,136.44	47%	53%	7.00%	5.00%	$ 2,155.43	$ 18.99	$ 6.98
2023	5.00%	$ 2,243.26	47%	53%	7.00%	5.00%	$ 2,263.20	$ 19.94	$ 6.79
2024	5.00%	$ 2,355.42	47%	53%	7.00%	5.00%	$ 2,376.36	$ 20.94	$ 6.60
2025	5.00%	$ 2,473.19	47%	53%	7.00%	5.00%	$ 2,495.18	$ 21.98	$ 6.42
2026	5.00%	$ 2,596.85	47%	53%	7.00%	5.00%	$ 2,619.93	$ 23.08	$ 6.24
2027	5.00%	$ 2,726.69	47%	53%	7.00%	5.00%	$ 2,750.93	$ 24.24	$ 6.07
2028	5.00%	$ 2,863.03	47%	53%	7.00%	5.00%	$ 2,888.48	$ 25.45	$ 5.90
2029	5.00%	$ 3,006.18	47%	53%	7.00%	5.00%	$ 3,032.90	$ 26.72	$ 5.73
2030	5.00%	$ 3,156.49	47%	53%	7.00%	5.00%	$ 3,184.55	$ 28.06	$ 5.57
2031	5.00%	$ 3,314.31	47%	53%	7.00%	5.00%	$ 3,343.77	$ 29.46	$ 5.42
2032	5.00%	$ 3,480.03	47%	53%	7.00%	5.00%	$ 3,510.96	$ 30.93	$ 5.27
2033	5.00%	$ 3,654.03	47%	53%	7.00%	5.00%	$ 3,686.51	$ 32.48	$ 5.12
2034	5.00%	$ 3,836.73	47%	53%	7.00%	5.00%	$ 3,870.84	$ 34.10	$ 4.98
2035	5.00%	$ 4,028.57	47%	53%	7.00%	5.00%	$ 4,064.38	$ 35.81	$ 4.84
2036	5.00%	$ 4,230.00	47%	53%	7.00%	5.00%	$ 4,267.60	$ 37.60	$ 4.71
2037	5.00%	$ 4,441.50	47%	53%	7.00%	5.00%	$ 4,480.98	$ 39.48	$ 4.58
Total per Capita									**$ 162.88**

MPR	0.165
Inflatiion	0.085
Interest rate	0.08

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