Impact analysis of distributed generation and RE based distributed generation on Indian economy and economy of BoP

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In the current economic scenario, India is focused on reducing its energy deficit by expanding its grid penetration, which is far less when compared to other developing & developed nations. Increasing its renewable energy capacity is also the top-priority for India. In the coming two decades India is predicted to become one of the largest economies of the world. Its unique geography, demography and current state of economy compels it to bring new models to reduce its dependence on oil and coal as a primary source of energy. In this work we have analysed the implications of distributed power production in Indian context and how it solves many problems persistent at BoP (Base of the Pyramid) within the country since independence. Based on certain assumptions, an in-depth financial impact of a decentralized power production facility on Indian economy has been shown and compared to centralized power production facility. Benefits of distributed production over centralized production have been further extrapolated in light of the ever declining share of agricultural sector in Indian economy. We also see the effect of renewable energy based decentralized power production system with reference to India's many steps aiming to proliferate RE (Renewable Energy) in the coming decade and its contribution in establishing RE instruments as consumer products in the country. A case study pertaining to the operation of salt farmers in the Kutchh region of Gujarat has been undertaken to quantify the impact of decentralized production. Results of case study allow us to study micro-economic and macro-economic implications, which will lead to future changes in energy policies of the country, of distributed generation. A virtuous cycle, based on these implications, has been drawn and the effect of the cycle on the business and economy at BoP has been discussed.

JEL codes: Q28, Q43 and O38
Keywords: Distributed generation, Renewable energy, Agriculture, Base of Pyramid

1) Introduction

India is a rapidly growing economy and is currently growing at the rate of 9% annually, and is further predicted to continue growing at this high rate. According the many estimates, Indian economy is poised to become the world's third largest economy by 2030, only after China and United States. With such high rate of growth in the economy of India, its energy needs are expected to proliferate at a very high pace. Managing its rapidly growing energy needs is turning out to be one of the biggest problems for the country.

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Energy is deemed as one of the most crucial factors for the rapid and inclusive growth of the nation as a whole. Currently India has the total installed grid capacity of 182 GW for electricity generation. If the country continues to rise at an average annual growth rate of 8%, its installed electricity capacity is expected to reach up to 950 GW within two decade. In 2010, India suffered a 12% gap in average demand and supply over the year and approximately 15% on peak load demand. India has a grid penetration of 65% which is very less when compared to other developed or as well as other developing nations. This low-grid connectivity effect gets worsened considering the fact that more than 70% of population lives in rural India. Even many grid connected rural areas face acute shortage of power. Electricity supplied is also very irregular and unreliable. With heavy dependence of rural economy on agriculture, this has lately turned into major detrimental force for the rural development and hence also restricting the country from harnessing its true growth potential.

To meet this huge expected demand of energy requirement, it is needless to say the need to shift towards renewable sources of energy. In 2010, renewable energy contributed a mere 17GW, i.e. 9% of the total installed capacity of the country. Country's dependence on conventional sources is still much more than its dependence on RE. But, Indian government has lately started to reform the energy sector of the country that favours RE. With the establishment of SERC and CERC, introduction of Electricity Act 2003, NEP 2005 and NTP 2006, government of India is trying to augment the scope of RE in Indian energy industry. Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) is also an initiative of the government in order to penetrate the rural areas of the country. Jawaharlal Nehru National Solar Mission (JNNSM) has also been started in order to increase the contribution of solar power in India which can be a big changing factor considering India's geographical position and the concentration of rural population in areas receiving high sunshine. All these steps are taken keeping in mind the two fundamental points:

- Increase rural electrification in order to further escalate the growth of Indian economy.
- Change from conventional sources of power to non-conventional sources so as to reduce dependence on fossils.

One of the sustainable paths that consider both these points is decentralized renewable energy production for such masses which involves a huge market at BoP (Base of Pyramid).

Unique geography, demography, a huge population living in rural areas and inadequate grid gives India a unique opportunity to exploit decentralized electricity production. Increasing manufacturing capacity, R&D and IP creation done for region specific problems and a huge scope for various innovative business models may lead Indian policy makers to focus on decentralized energy production.

2) Methodology

We have considered two different verticals of decentralized power production – financial and social. First vertical deals with the financial impact of a decentralized power production facility and the second vertical deals with the social impact on rural India. Based on certain assumptions, a sample calculation has been carried out to determine the unit cost of electricity delivered from a CCP (Combined Cooling and Power) type centralized production, CCP type decentralized production and CCHP (Combined Cooling Heating and Power) type decentralized production. It clearly allows us to compare the economies of scale concept for a larger grid-connected power plant with the cost benefits of a smaller distributed power plant.

As we move forward to social impact of distributed power generation, we analyze the multiple problems at base of the pyramid of Indian economy, with special emphasis on agricultural sector, and how decentralized power generation model can help eradicating them. In the subsequent section, special focus has been given to a RE based decentralized production facility as we dwell over the edge that RE possess keeping in line with the recent energy policies in India. We have then carried out a small case study of Kutchh region in Gujarat and calculated the impact that a wind-power and wind-solar hybrid based decentralized production facility can have on the life of the salt farmers. Based on the above inferences and calculations, we have outlined the economic implications of a decentralized power production facility in India. Concept of decentralized electricity directly leads us to a self-sustainable model in rural India. This self-fuelled model is represented in the form of a cycle and emphasis clearly on its impact on rural India.

2.1) What is decentralized or distributed electricity?

As per the Government of India, decentralized power production facility is defined as any facility that produces power less than 100kW and is not connected to central grid. These are stand-alone systems that supply power to a particular commercial/domestic setup. Due to unavailability of grid the management of power produces is more difficult for such systems however there are no grid losses and voltage problems associated with it. These systems are characterized by an energy storage device in form of batteries. The storage also has capacity to run 24 hours of normal operation of the setup. Decentralized electricity has some very fundamental differences compared to centralized electricity production.

Decentralized Electricity	Centralized Electricity
Not connected to central grid	Connected to central grid
Production is generally in near vicinity of consumption	Production is generally remote from the point of consumption
Energy storage is the most common method of power management	Power evacuation is most common method of power management

Per watt cost is higher	Per watt cost is lower
Characterized by small production capacity	Characterized by large production capacity.

2.2) Financial impact – A sample calculation of cost of per unit power delivered

As the electricity needs of the society increased, larger power plants were built away from civilization. To transfer electricity complex transmission and distribution channel was also built. These large power plants gave economies of scale and hence became more economic in the context of the technology. Today, the presence of smaller generation technologies has changed the thinking. Technologies such as the combustion turbine, reciprocating engine, fuel cell, and photovoltaic are small-scale technologies that can be used at or on a site close to the end user. Technology has advanced to the point where there is less of a need to build large, expensive power stations when extra capacity is needed—economies of scale is no longer a viable argument for building large power plants.

Decentralized power plants are actual plants employing central plant generation technologies that are located near users. These combined heat and power (CHP) plants achieve 65%-97% net electrical efficiency by recycling normally wasted heat, and by avoiding transmission and distribution losses. Waste of energy from the worldwide electricity system is around 67%. Most of the losses are from central thermal plants that cannot recover and use the waste heat. Considerable losses also arise from transmission of the energy from producer to consumer.

Looking to such a widespread deficit of supply compared to demand, it would be worthwhile considering whether we should duplicate energy transmission infrastructure all over the country – i.e. one gas pipeline network and electricity transmission and distribution network. In fact, instead of thinking of gas based mega power projects which will be prone to lot of T&D losses before the generated power could actually reach the consumer, it would be prudent to set up a widespread gas transmission and distribution network and set up a number of localized small and medium size power plants. It is important to consider the cost of power delivered rather that generated (Generation plus Transmission and distribution cost seen together). When seen from this perspective, the fallacy of the “economy of scale” argument in favour of Mega Power Projects will be obvious. A sample calculation was carried out to compare the economics of centralized mega power plants versus distributed generation. The results are tabulated below:

(all figures in crores)

	Centralised Generation **CCP** **2500 MW**	**Distributed Generation** **CCHP** **2100 MW**	**Distributed Generation with CCP** **2100 MW**
Delivered Power	2000 MW	2000 MW	2000 MW

Generation	10,000	10,500	10,500
Incremental T&D	10,000	1,050	1,050
Total Capital Cost	20,000	11,550	11,550
Fuel Cost for 20 Years	58,800	24,696	49392
Total Life Time Cost for 20 Years Operation	78,800	36,246	60,942
Unit Cost of Generation	Rs. 4338/MWHR	Rs. 2216/MWHR	Rs. 2,988/MWHR

Assumptions:

Capital Cost

Centralised Generation Rs.4 Crores/MW

Distributed Generation Rs. 5 Crores/MW

T&D Losses

Centralised Generation 20%

Distributed Generation 5%

Fuel Consumption

Centralised Generation-CCP 210 NM3/MWHR

Distributed Generation-CCP 210 NM3/MWHR

Distributed Generation-CCHP 105 NM3/MWHR

(Source: Centre for Fuel Study and Research)

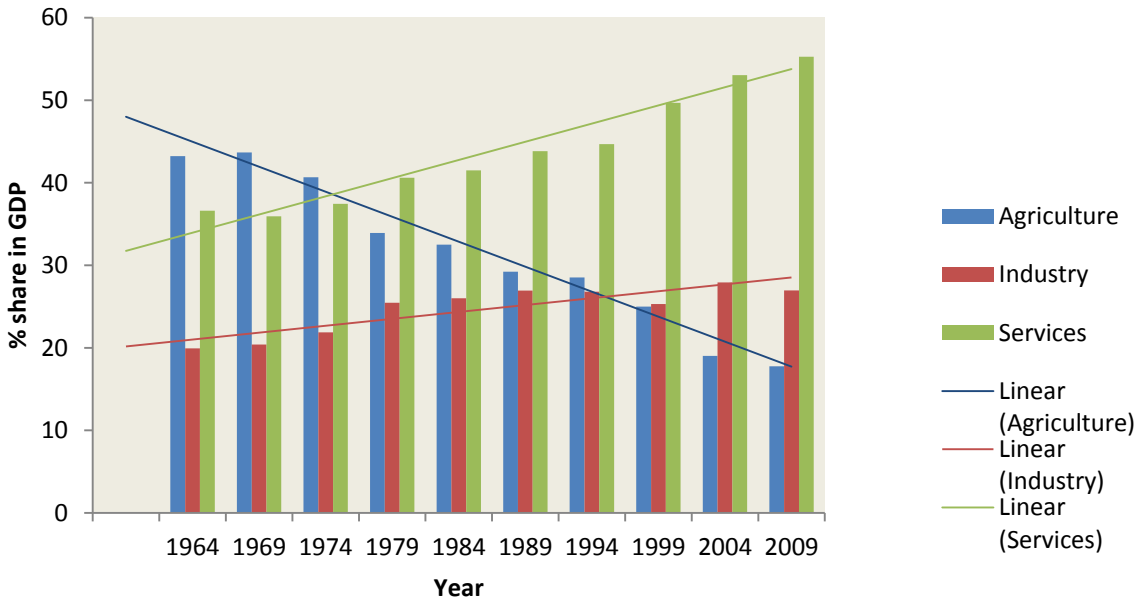
Large central power plants cost less to build than smaller local power plants, but:

- One new KW delivered from central power plants requires 1.5 kW new plant (55,500 Rupees) and 1.5 KW new T&D, (87,000 Rupees); total of 142,000 Rupees
- One new kW delivered from DG requires 1 kW new generation (50,000 Rupees) plus 0.1 kW new T&D (3,700 Rupees); total of 53,700 Rupees per delivered kW.

2.3) Problems at BoP - Economic scenario at rural India

In India, BoP primarily constitutes the population associated with agriculture sector in rural India. According to the definition of World Bank, 1.7 billion people in the world are below poverty line out of which 0.4 billion are in India alone.

There is a growing disparity between growth of urban India and rural India. Also, evident unmanageability in the growth of urban India is the result of poor infrastructure and lack of developing ecosystem that is sustainable. Growth of agriculture sector, which is the primary occupation of the rural people, has been nearly negligible when compared to either manufacturing sector of services sector.

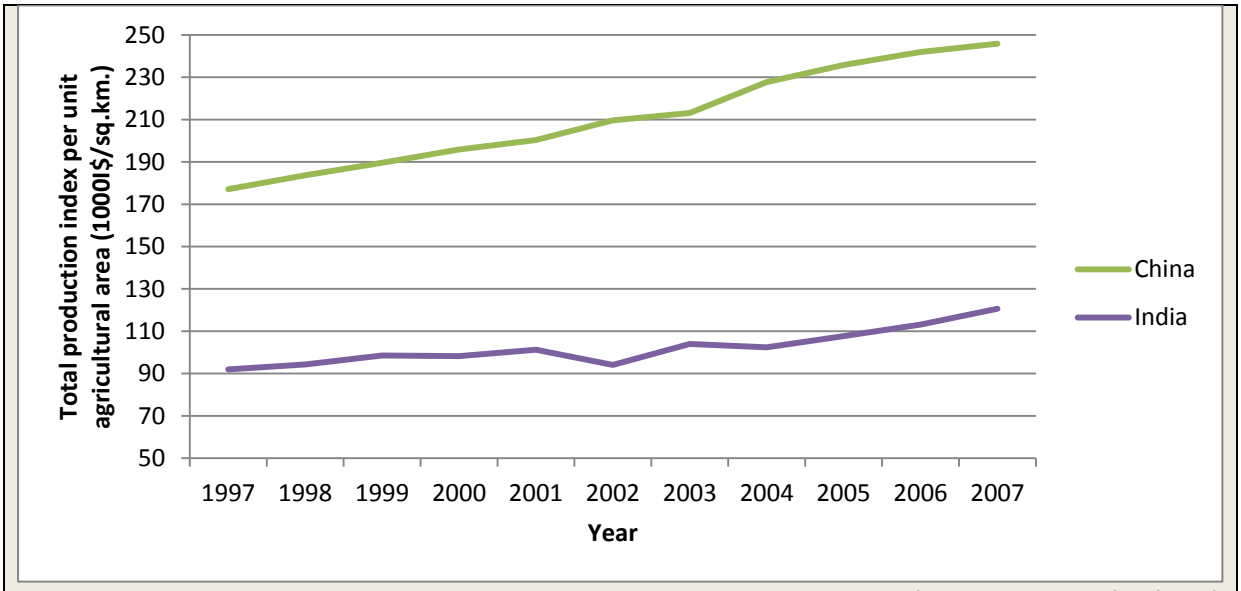


Lack of any major commercial activity requiring skill and education in the rural area itself has fuelled urbanization in the country. Lack of commercial activities can be attributed to the unavailability of basic infrastructure in the rural India. This scarcity of basic infrastructure has also stopped the section of rural population having a significant purchasing power from attaining a reasonable standard of living. Problems like food security are further boosted from dearth of infrastructure. Almost 35% of the perishable food is wasted due to inadequacy of appropriate infrastructure, about half of which comes from the first logistic link near the farms in rural areas. Various FMCG companies and financial organisations (banks & microcredit companies) have tried to penetrate this market to tap the huge potential at BoP, but only with limited success.

The gap in standard of living and income in rural and urban areas has forced policy makers to take concrete steps in the direction of inclusive growth. As a recent measure, government of India has targeted agricultural growth rate of 4% in its 11th five year plan. Many of these problems can be solved by strengthening rural economy through appropriate supply of energy. The major problem with rural growth is very poor grid penetration and highly irregular supply of energy.

Comparison of India's and China's agricultural growth in the last decade

India and China are two of the world's most growing economies. India's total agricultural area is nearly equal to that of China despite the fact that total land area of China is nearly three time of India. Also, during the past 10 years, percentage of agricultural area of both the countries has remained nearly constant.
Agricultural area of China = 1444364 sq.km.
Agricultural area of India = 1413523 sq.km.



(Source: OECD database)

In the beginning of the last decade, India's total production index was nearly half of that of China. While India's total agricultural production has witnessed slow growth, China's production has been proliferating tremendously thereby making China the largest agricultural country in the world.

One of the possible solutions is electrifying these remote areas through grid connection. However due to practical problems of electricity theft and no system setup for the payment such measures have been unsuccessful. Thus decentralized electricity can become the way forward as a solution to this problem. It will allow the system to be more robust and sustainable since control can be transferred to end user directly.

2.4) Advantages of Decentralized over centralized in Indian context

Considering the unique demographical and geographical position of India and collating it with the current and the predicted future economic scenario of the country, we can say that decentralized electricity possess an edge over centralized electricity for the rural and off-grid electrification in India in the coming years.

- **Minimal losses:** India suffers from extremely high transmission and distribution loss. These losses account for 27% of the total electricity production of the nation. Decentralized production means that there are no grid losses and hence a huge portion of electricity that would be lost can be saved. Also, there won't be issues pertaining to grid related power evacuation or power management in decentralized production. For instance, if we need an effective power output of 5000MW from centralized power facility, we must install at least the power capacity of 8000MW which will also account for all the losses. But, the same power output can be generated by installing 5500-6000MW in decentralized power facility.
- **Cogeneration:** Cogeneration is the use of a heat engine or a power station to simultaneously generate both electricity and useful heat. Centralized

production facilities are never located near the revenue area of the inhabited land and so it is not feasible to use to this extra heat energy for other purposes. A possible solution which allows us to utilize the otherwise waste energy is setting up plants in the proximity area where that heat can be utilized. Decentralized production facility sited close to inhabited area could then use their waste heat. Facilities sited close to or at industrial sites could use their waste heat for a variety of industrial processes.

- **Easier Set-up, Maintenance and Operation:** Unlike centralized power production, a large land mass is not required for decentralized production. Set-up and maintenance of decentralized energy facility requires more manpower per watt as compared to centralized production facility. Off-grid decentralized power production facility does not need complex controls for its operation and thus highly skilled labour is also not required. Hence, requirement of less skilled manpower would directly result in the decrease of unemployment in the area.
- **Opportunity for SMEs and entrepreneurs:** Indian SME's contribute only 8% to total GDP compared to world's average of 65%. SME's contribute ***22%*** of the total employed population in India. Decentralized electricity would also ensure the use of locally available resources and enhance productivity and production of electricity. This provides an excellent opportunity for SMEs. They are expected to contribute 22% alone to the Indian economy in 2012. Thus creating new opportunities for SMEs would further help in escalating Indian economy.

2.5) Decentralized production based on renewable energy in India

Gas/fossil fuel can be a viable option for energy production, but setting up infrastructure for gas/fossil fuel supply over a wide region will be a huge infrastructure investment that will also take considerable time. Setting up decentralized power production facility based on RE can drastically reduce infrastructure investment which can then be transferred for subsidizing renewable energy production which will run on very less operation cost. It will also aid in solving the problem of India's heavy dependence on imported fossils. Decreasing its fossil fuel import bill and simultaneously increasing rural electrification can thus be tackled by decentralized renewable production of electricity.

Different regions in India are endowed with a wide variety of resources that can be used as fuel. A large portion of coastal regions have a huge wind power potential. Many remote locations in the region of western desert, wind power can be employed to generate electricity and run irrigation pumps. India also possesses the highest potential in the world to harness solar power and thus MNRE has recognised solar power as a major source of energy in future for India and has created ambitious plan in Jawaharlal Nehru National Solar Mission (JNNSM). JNNSM has also been integrated with RGVVY of Ministry of Power and RVE programme of MNRE. Wind

and Solar power resources complement each other perfectly in Indian climatic cycle. Wind-solar hybrid systems can be very effective solutions.

Case study of Kutch region of India

Purpose: This case study shows the potential of renewable based decentralized energy to effectively solve the energy problems at the BoP. It effectively utilised the local resources and creates an adequate local solution. Ahmadabad based GIAN experimented with a similar solution in this region.

Background: Kutchh is one of the largest salt producing regions of India. The ground water of this region is extremely saline and is easily available at very low depths of about 10 to 15 feet. Since this is one of the most remote region of India with a very low population density, it is not connected to grid. Salt farmers use diesel pumps to pump water from the ground to make salt. The majority of their income is spent on fuel costs.

The cultivation season for the salt farmers starts from October and continues throughout the month of May. During monsoon seasons the sea waters flood the region and it becomes inhabitable. Food and other essentials are regularly supplied to them by nearby village traders in trucks and it also contains a regular supply of diesel. These farmers end up paying very high prices for diesel and other necessities.

Economics of salt production:

- Salt PAN size: 50ft x 50ft
- Water requirement: 5lit/KG
- Average salt production: 800tonnes/PAN
- Average no of pans owned by a farmer: 5
- Total water requirement: 40,00,000 litres/pan
- Avg. cost of diesel for pumping water: INR 19/1000litres
- Cost of diesel for pumping water: INR 76,000

Decentralized renewable energy as the solution: Kutchh region has one of the best solar radiation and wind profile in India. This region is ideal for decentralised wind power and solar power generation. We propose a solution based on these renewable resources. The energy thus generated can also be used to run small domestic appliances and improve their quality of life.

	Wind Powered Solution	Wind-Solar Hybrid Solution
Rated power of aero generators	3.5kW	2kW
Solar Panels	-	1.5kWp
Daily energy produced	14kWh(@19%PLF)	14-15kWh
Water pumped/day	79350 litres	79350 litres
Total water pumped	190,44,000 litres	190,44,000 litres
Aero generator cost	-	INR 3,10,000
Solar panel cost	-	INR 2,00,000
Total Cost	INR 4,50,000	INR 5,10,000

Simple Payback	6 years	7 years
Government Subsidy	INR 3,50,000	INR 3,50,000
After Subsidy	INR 1,00,000	INR 1,60,000
Simple Payback	<2 years	<3years

Wind-solar hybrid solution is better than the fully wind solution. Wind power yield is highly erratic in nature. The maximum production occurs during summers. This is also the time when we can achieve maximum output using solar energy. Since solar energy reaches its peak during high sunshine timing it will produce maximum power during the highest evaporation timing and thus load pattern is naturally matched. Due to these unique reasons, this system will not need any complex electronic controls

3) The Findings – Economic implications of decentralized power production

3.1) Microeconomic implications:

Problems pertaining to the base of Indian economy can be solved with focussed localized solutions. The major source of income at BoP is agriculture and agriculture related activities. A lot of SME's can also create intellectual property and provide solutions. SME's employ more people per unit of revenue earned than the bigger companies and thus create large employment opportunities for skilled rural labour force. Due to a wide variety of consumption patterns very different unique business models are possible for BoP. SME creation can thus solve the problem of employment of skilled labour in rural areas.

Availability of easy decentralized electricity based on localized resources can fuel the growth of other economic activities which would be supplementary to agricultural sector like food processing industry. It will also bolster dairy industry due to huge cattle stock that is available in rural areas. Increasing penetration of communication, transport infrastructure and growth of credit and financial inclusion can further aid the development initiated by regular supply of electricity. This will in turn increase the purchasing power of the rural masses. This can be a boost to economic activity and has a great potential to improve the human development index of such areas.

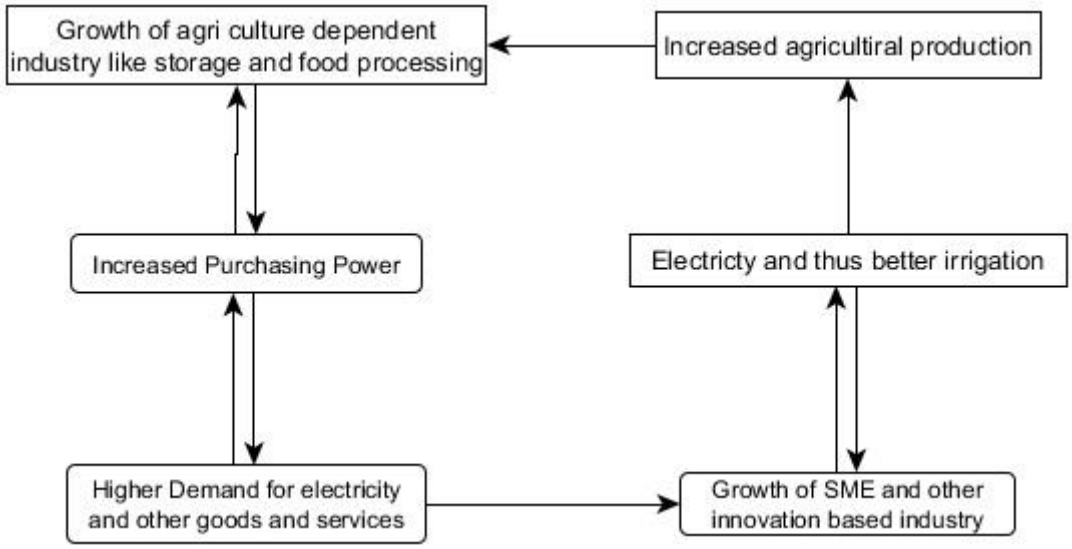
3.2) Macroeconomic Implications

Agriculture contributes 15-20% of India's GDP varying annually according to the monsoons. Agriculture employs almost 50% of the population, majority of which lives in rural areas and are among the poorest in the country. For these markets to develop enterprise creation is a necessity. For enterprise creation and a correct eco system for entrepreneurial activities to flourish, a reliable energy supply is essential. Govt. Subsidies involved with various programmes like RGVVY, RVE and UIDAI are first steps towards achieving this. With this India can overcome its problem of food security and boost its food exports in a very short span of time. Due to a huge contribution of agriculture in the economy, a minor improvement in this sector can

bring huge results in India's overall economic performance and Human Development Index.

3.3) Virtuous cycle

BoP is a much interconnected economy with agriculture and related activities at its centre. The key to reforms in rural India lies with solving problems in this sector. As discussed previously the energy can be a key enabler of the growth at BoP. Energy can enable irrigation in these areas. Farmers can utilise their lands for two or three crops in a year. This energy services provider in forms of SME can promote local entrepreneurship and can provide employment to the skilled labour in rural areas. Agricultural growth can also stimulate the food processing and storage industry. This will result in higher purchasing power for the consumers and that will further increase the demand for energy. Thus this creates a whole virtuous cycle, which is illustrated below, where the growth of these areas can be achieved sustainably.



3.4) Recommendations

Models based on the following production system can be implemented in India with success.

- Semi centralized production: This solution basically means creating a power production facility that can serve a particular village/community or a cluster of villages/communities. This facility can be operated by a local enterprise that will create employment and purchasing power at rural level. These plants can be made to operate at optimum level that can accommodate the local consumption pattern. The issues of theft, revenue collection etc. can be easily sorted out. The plants can be operated on localized resources like bio-mass, wind or solar power. Different revenue models can be an option according to consumption pattern for different economic classes at rural level. Energy

retailing can be a very viable and promising business model. This presents a wide scope of business model innovation at BoP. It can also easily run on govt. Subsidies involved with various programmes like RGVY, RVE and UIDAI. Govt. Can directly subsidise the consumer based on the central subsidy plans through UIDAI.

- Completely decentralized consumer based production: This is a more involved option where each consumer shall be given a solar or solar/wind hybrid solution as a kit according to local resources. This will involve more R&D that can make the products more suitable to local wind and solar resource. One such cluster can be operated where ownership of instrument and power produced is given to the consumer. Subsidy can be directly transferred to the consumer. A local grid can be setup where excess production can be fed for those who can't afford the capital expenditure. This will create a large pool of local entrepreneurs and this can be an additional source of revenue for such families.

Aside from the above mentioned changes, the advantages of decentralized production should be considered while reforming policies in near future. Some basic points to be considered during the reformation:

- Pushing the policies toward decentralized or semi-centralized energy production.
- Creating eco system for the sustainable development and diverting subsidies towards infrastructure development.
- Resource based regional capital support to decentralized energy and renewable energy based decentralized energy.
- Eco system for SMEs to supply energy for rural areas and regulating them. Empowering them to collect revenues and deal with electricity theft.
- Policy space for innovative business models to operate and better integration of financial institutions with SMEs and rural consumers.

4) Summary and Conclusions

India has been sustaining a growth rate of 7-8% in last decade with majority of growth coming from services and manufacturing & industrial sectors. The agriculture in India has almost stagnated. Thus, inclusive growth has become a major agenda for the government. Economic and reliable energy supply can go a long way solving this. In order to meet the energy need alternative ways and strategies need to be developed. Decentralized electricity production offers a very innovative solution to this problem. India has a plan to double the generation capacity in next ten years. It needs to review the policy followed hitherto of encouraging large sized Central Power generation and rather think about encouraging distributed generation with

utilisation of waste heat by employing CHP/CCHP technologies. Decentralized electricity is not as capital intensive as centralized. For a cash strapped economy like India this is an important factor. Due to higher efficiency, this can lead to a substantial savings on fuel costs and better environment compliance. It can create ecosystem for small entrepreneurs in rural areas. This can make operation easier for the government as they will be regulating these agencies (private or PPP based) and will not be directly involved with the consumers. Introduction of UIDAI, credit availability and better transport infrastructure can be a great boost to this sector and a huge growth can be achieved. Introduction of electricity can activate the virtuous cycle for the rural growth in India and emerging rural markets can be a huge opportunity for many firms in India and the true potential of business at BoP can be harnessed. Indian enterprises with better understanding of this market are better poised to exploit this opportunity.

Renewable energy is a very viable option for the decentralized generation at rural level due to minimal operation cost. Different regions have different resources and these resources can be put in to effective use for renewable energy production. Bio-mass and solar can be a major source of energy for decentralized production. This new model for providing electricity can open up avenues for entrepreneurs to come up with innovative business models for the local problems. Increased purchasing power and better agricultural efficiency can bring the prosperity and increase the Human Development Index.

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