MASTER

# Upscaling of niche experiments in PV solar energy for transition to sustainability in India

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## Preface and acknowledgment

This thesis is written for fulfillment of Master of Science in Technology and Policy of the Department of Industrial Engineering and Innovation Sciences at the Eindhoven University of Technology.

There is an interesting story to this research as the idea for this research was given to me by my first supervisor Dr. H A (Henny) Romijn way back in November 2008 when I had just started the master's programme. I wrote a small paper for a master course Capita Selecta and discussed up scaling of solar water heaters in India. Later I decided to carry out similar kind of research but in a more extensive way. I also had the opportunity to conduct the research in India and also apply my knowledge in solving sustainability related issues in my country.

This thesis would not have been possible without the support and guidance from many people. First I would to thank my first supervisor Dr H A (Henny) Romijn who has not just been a supervisor but a mentor for me for my entire master's programme and has guided me throughout the master's programme. I also want to thank my second supervisor Dr Ir. R. P J.M Raven who has not only helped me in this research but also taught me courses related to transition studies and system of innovation which form the basis of this research. Apart from them I would also like to thank all other teachers Dr Ir. Geert Verbong, Dr Ir.Anneles Balkema, Dr Saurabh Arora, Dr Bart Sadowksi and several other teachers who have taught me several courses to build a strong base to carry out a master research project. I would also like to extend my deep regards for Ria Overwater and International Student's Office which helped me getting a scholarship for master's programme. In Eindhoven I would also like to thank all my friends Eddy, Alok, Tom, Naomi, friends from TVO and many more I met here in Eindhoven.

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A special thanks to my parents, grandparents and other family members who have always been supportive of what I have done and encouraged me. This research would not have been possible without them. Last a special thanks to all the 'musicians' specially Ustaad Nusrat Fateh Ali Khan sahab and A R Rahman who have inspired me a lot as music provides me a lot of inspiration for research and life as well. I hope you will enjoy reading this thesis.

Suyash Jolly

Eindhoven

9 th August, 2010

## Summary of Research


Emerging nations such as India are at a cross roads with dual agendas of reducing energy poverty, improving energy security as well as reducing green house gas emissions. India is characterized by rapid economic expansion which is likely to increase the energy demand. However currently India faces several issues such as energy poverty with large number of people lacking access to energy, power losses, issues with respect to security of supply, rapidly increasing urban rural divide and excessive dependence on fossil fuels. To counter these issues there is a need for system level transformation with radical changes in technological, social, cultural and behavioral changes rather than end of pipe measures alone. The emerging field of transition studies which is highly multidisciplinary in nature and developed by Dutch researchers offers some path breaking insights into how we can lead into new socio technical systems with radically increased environmental and social performance.

The emerging field of transition studies which has been build upon economics of innovation, evolutionary and neo-institutional theory, complex systems theory, political science and history and sociology of technology, emphasizes that technological, institutional and societal change need to be seen as embedded in one another. The literature discusses transitions as the result of multi level dynamics emphasizing lock in and stability at the meso level of socio technical regimes; radical innovation and experimentation at the micro level of niches under the influence of external pressure emerging from changes at the macro level of the socio technical landscape (Geels, 2002). Experimentation in niches which are defined as (a coherent set of rules and institutions that enables and constrains the choices and behaviour of regime actors including firms, users, policy actors, scientists, etc and the selection environment for innovations) takes place through the processes of dynamics of expectations, network formation and single and double loop learning under Strategic Niche Management. (Kemp et al.1998; Raven, 2005).

Emerging niches such as Photovoltaic (PV) have the potential to solve some of the problems created due to the current socio technical regimes i.e. fossil fuel based energy system. PV technology is expanding very rapidly due to technological innovations. PV is a commercially available and reliable technology with a significant potential for long term growth in nearly all world regions. PV is projected to provide 5% of global electricity consumption in 2030 rising to 11% in 2050. It also has the potential to meet other development challenges such as rural electrification, energy provision and more generally poverty alleviation. In this respect there is a need for widespread diffusion and scaling of PV technology to address global challenges of sustainability and energy poverty (IEA, 2010). Thus sustainable technologies such as PV will be fundamental to energy transitions but key question arises as to how they can become widely adopted. This leads us to the main research question

**How has the PV niche developed in India and what are the different dimensions and mechanisms through which it can upscale and transform the dominant sociotechnical energy regime?**

### Research framework

In the past the transitions studies framework has been applied for sustainability transitions in developed nations (Netherlands, U.K. and other EU nations),but to apply the framework to developing nations such as India will require lot of modifications. An important challenge is to connect the sustainability agenda with the agenda of low carbon development, poverty reduction and local community development and capacity building. This is however difficult in context of developing nations due to multiple institutional failures, politics involved in steering transitions and lack of know how to build viable niches. Currently lots of initiatives are going on in the form of sustainability experiments (Planned initiatives which embody a highly novel socio technical configuration which is likely to lead to substantial sustainability

gains). However an important question is to understand how experiments and niche can up scale. (Berkhout et al, 2010; Raven et al, 2010; Romijn et al, 2008).Little is currently known about the phenomenon of up scaling specially in the context of developing countries. Furthermore the concepts from transition studies have been mainly applied in developed nations. This research is an important step in understanding key barriers, dimensions and mechanisms in up scaling of niches and experiments in the context of developing nations such as India. To answer the research question we develop a framework based on existing literature on transition studies, social and sustainable entrepreneurship, strategic management, bottom of pyramid and development studies and develop insights into upscaling using the methodology which is discussed below. The theoretical framework developed tries to link upscaling at the niche level i.e. meso level with the level of experiment i.e. micro level since this dual perspective at the micro as well as the meso level complement each other.

**Methodology and data collection**

We use the case study methodology as the main guiding analytical approach (Yin, 2003).Data collection included qualitative and quantitative sources including academic publications, primary and secondary sources (e.g. reports from research institutes and consultancy firms, websites, internet blogs, presentations in seminars, newspaper articles, trade journals, policy documents) as well as interviews with key stakeholders and site visits to different experiments. Theoretical insights were developed using the case study methodology. (Eisenhardt, 1989; Yin, 2003)

**Analysis and conclusions**

Some important conclusions from the research are that transition in India is hindered largely by vested political interests and complex institutional governance structures. The complex governance structure of India presents lot of challenges in understanding how niches and experiments can up scale. India is also highly dependent on transnational and global linkages i.e. international between national governments, between firms, between industry and academia which can help developing countries such as India leap frog towards low carbon development pathways. From our analysis we also found out that successful up scaling requires a two level approach i.e. meso at the level of niches and micro i.e. at the level of experiments since upscaling is a multifaceted process involving linkages between different levels. Furthermore findings from this study can also be used for studying other technologies in different contexts i.e. other developing countries.

**Policy recommendations**

Indian policy makers can stimulate up scaling of niche and experiments through stricter regulations on the dominant fossil fuel based regime through (financial and regulatory instruments like carbon tax, emission trading schemes, emission norms, and performance standards) on regime and by providing various kinds of protection mechanisms (Economic, institutional, socio cognitive, cultural, geographic and political) to emerging niches. Stable political environment, regulatory support and good governance mechanisms are highly essential since the current multi party political system, institutional framework with embedded distributive politics have created an institutional and political legacy which resists development of promising niches. Policy makers should focus on developing transnational linkages such as direct or indirect relationships with foreign technical experts, multinational technology suppliers, maintenance firms, joint ventures and licensing agreements and overseas development assistance. Collaborative efforts between developing and developed nations through international negotiations, conventions and agreements on climate change, emissions trading, development assistance and intellectual property rights negotiations are also highly essential. National policy makers also need to develop adequate linkages with global and transitional actors in energy such as International Energy Agency, Energy Charter treaty, G8, European Union, APEC, World Bank, World Trade organization, APEC etc since they are likely to play an important role in global energy transitions.

**List of figures**

**List of tables**

# Chapter 1 Introduction

## 1.1 Background information

Universal energy access can be defined as access to clean, reliable and affordable energy services for cooking and heating, lighting, communications and productive uses (The Secretary General's advisory group on energy and climate change AGECC, 2010). Billions of people live without access to modern energy services. About 1.5 billion people still don't have access to electricity, and around 2.5 billion people rely on traditional biomass as their primary source of energy. It is widely accepted that this lack of access to affordable, reliable, energy services is a fundamental hindrance to human, social, and economic development and is thus a major impediment to achieving the Millennium Development Goals (MDGs). Current efforts are insufficient in scale and scope and attempting to address the [1](Srivastava et al, 2006; Urban et al, 2009).

Given the centrality of energy issues in the overall climate change debate, the role of energy technologies, particularly low cost, pro poor, and sustainable energy technologies should arguably be one of the crucial components impacting future action related to global climate change. Increasing access to cost effective, environmentally beneficial energy technologies and systems has also long been seen as critical in the global struggle against poverty. Thus the issues of reducing global climate changes through low carbon technologies and poverty reduction are highly interlinked (Cherian, 2009).

Energy poverty in developing nations has a major rural dimension since a large section of rural population faces problems due to lack of energy services. Some of the problems facing rural electrification in most developing countries include inadequate policies, weak institutional frameworks and limited financing. (Haanyika, 2009). This has resulted in huge government deficits, wastage of scarce groundwater resources on inefficient irrigation and a lack of funding for enhanced electrification.[2] Politicians in the developing world have been attracted to large infrastructure projects in order to secure reliable power for key economic centres. Liberalisation and privatization has often been advocated as a way to ensure the necessary investment in energy infrastructure. This model failed to address the different starting points and institutions existing within different countries. The drive for commercialization as part of electricity reforms also made the problem worse for rural areas since the expansion plans of grid electrification were restricted to urban and industrial areas only (Ockwell et al, 2010).

Even households which were reached by national grids often receive intermittent electricity. In absence of reliable electricity households across the world have been dependent on traditional sources of energy such as kerosene, candles, biomass and non electric sources of lighting .Apart from lost productivity poor people have also faced high recurring expenditure and time consuming process. Fuel based lighting is associated with soot, indoor air pollution and burns. Furthermore the consumption of fuel for lighting equivalent to 1.3 million barrels of oil per day, results in carbon dioxide emissions on the order of 190 million tons per year (Adkins et al, 2010).

Although there are many technologies available for providing energy services the solution to electricity access does not lie in selecting the winning technological innovation alone but also in developing mechanisms for effective delivery of its services and customization to user needs. Other challenges include involving local communities at various stages of planning and implementation. An equally big challenge is to involve local communities at various stages of planning and implementation of the

[1] http://www.makingitmagazine.net/?p=655
[2] http://www.makingitmagazine.net/?p=655

scheme. Therefore it is highly recommended to develop rural power technologies and solutions with specific end uses in mind. The figure below shows specific solutions for specific cases.

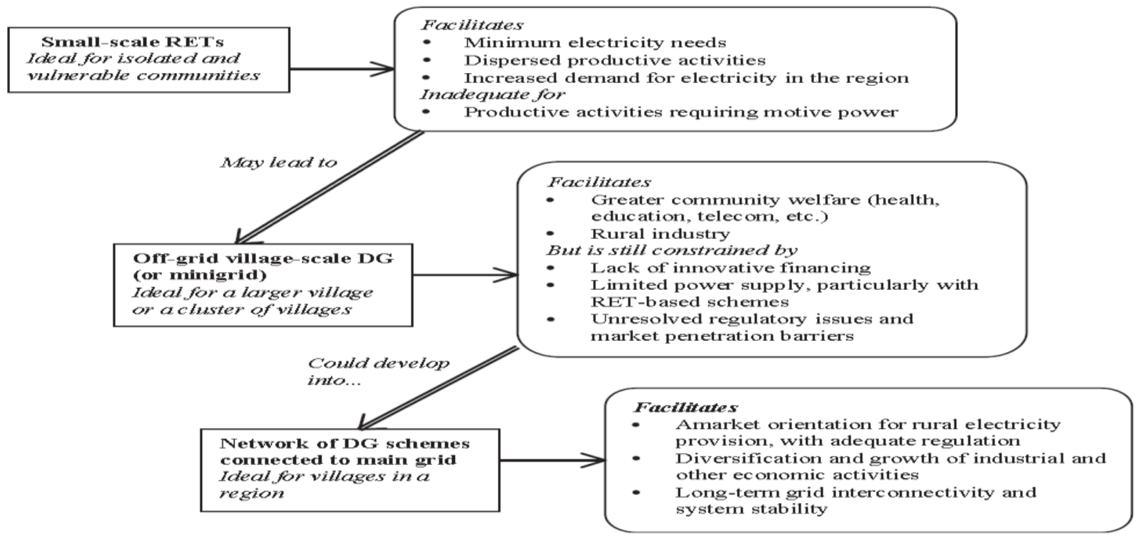


**Figure 1.1:** Framework for distributed generation schemes for electricity provision in remote areas(Source: Chaurey et al , 2004)

In the first phase small scale renewable energy technologies such as solar home systems for homes and dispersed productive activities can be provided through government subsidies and alternative delivery mechanisms with the involvement of local NGOs. These schemes will have certain positive impacts for the initial stages of development, particularly those of meeting the basic electricity demands (in the few tens of watts range). However they may not meet the requirements of a variety of commercial as well as social welfare activities that require power in kW and even higher ranges. In the next stage other renewable energy technologies such as biomass gasifiers, wind diesel hybrid generators and more advanced DG technologies such as micro turbines can additionally be deployed at the village level. They can be set up as off grid generation and localized distribution schemes and localized mini grids. The next phase can involve integration of various off grid schemes into the main grid network (Chaurey et al, 2004).

Therefore in this respect small scale solar home systems using PV technology can be useful for meeting the minimum energy needs of the people. PV technology is expanding very rapidly due to technological innovations. PV is a commercially available and reliable technology with a significant potential for long term growth in nearly all world regions. PV is projected to provide 5% of global electricity consumption in 2030 rising to 11% in 2050. It also has the potential to meet major development challenges such as rural electrification and energy provision and poverty alleviation. In this respect there is a need for widespread diffusion and scaling of PV technology to address global challenges of sustainability and energy poverty (IEA, 2010).

## 1.2 Basic information about PV technology

PV systems directly convert solar energy into electricity. The basic building block of a PV system is the PV cell, which is a semiconductor device that converts solar energy into direct-current (DC) electricity. PV cells are interconnected to form a PV module typically up to 50-200 Watts (W). The PV modules combined with a set of additional application-dependent system components (inverters, batteries, electrical components, and mounting systems) form a PV system. PV systems are highly modular i.e. modules can be linked together to provide power ranging from a few watts to tens of megawatts (MW). R&D and industrial development have led to a range of different PV technologies with different levels of maturity. Commercial PV modules may be divided into two broad categories namely wafer based c-Si and thin films. Crystalline silicon (c-Si) modules represent 85-90% of the global annual market today. C-Si modules are subdivided in two main categories single crystalline (sc-Si) and multi-crystalline (mc-Si). Thin films currently account for 10% to 15% of global PV module sales. They are subdivided into three main families namely amorphous (a-Si) and micromorph silicon (a-Si/μc-Si), Cadmium-Telluride (CdTe), Copper-Indium-Diselenide (CIS) and Copper-Indium-Gallium-Diselenide (CIGS).Apart from them there are several emerging technologies such as advanced thin films and organic cells.

PV systems can be connected to the utility grid or operated in stand alone applications. The investment costs of PV systems are still relatively high although they are decreasing rapidly as a result of technology improvements and economies of volume and scale. High investment costs or total system costs represent the most important barrier to PV deployment today. Total system costs are composed of the sum of module costs plus the expenses for the balance of system(mounting structures, inverters, cabling and power management devices) which includes the electronic components necessary to make PV module functioning (IEA, 2010).

Typical solar home systems using PV technology provide limited energy for lighting, and for operating TV or radio for limited time periods .However the demand and growth rate for energy services in rural areas tends to be relatively low and this has been a key justification for using solar energy technologies. The modularity of the systems has been noted as their main advantage over the grid in these cases enabling immediate full utilization of available capacity (Wamukonya, 2007).

However solar home systems using PV technology may not reach millions of people due to several barriers such as high costs etc to meet their basic lighting needs. In this respect lanterns that use light emitting diodes (LEDs) powered by batteries which in turn can charged by grid electricity or small solar panels have emerged as a cost-competitive alternative to kerosene and other fuel based lighting technologies offering brighter light for longer duration at equal or lower cost over time. Features which make portable LED lanterns a potential substitute for kerosene based lighting include durability, ability to direct light output and low DC voltage and wattage levels which permit low cost charging (Adkins et al, 2010).

Thus solar energy has large number of benefits for the poor. Solar lighting allows children to study at night without straining their eyes, aiding better school performance with all its attendant benefits. Light also provides greater opportunity for home working at night. Moreover a solar lantern instills a sense of security because the bright lights of solar lantern keep animals at bay and improved health due to avoided particulates from kerosene .These factors make solar lantern technology desirable from a socio economic perspective in rural households. As improved lighting solutions lead to improved security, literacy, and income-producing activities in the home solar lanterns have proven attractive for many rural households. Past experience suggests that existing lighting options such as solar photovoltaic (SPV) lanterns have been effective in switching rural populations to efficient and modern energy systems (Rehman et al,2010).

## 1.3 Energy scenario in India

The Indian power sector is highly dependent on coal as a fuel, with 53% of the total installed capacity consisting of coal based generation. Given the current scenario, coal consumption by the power sector is likely to reach levels of 173 mn MT by 2012. According to the Ministry of Coal, the existing coal reserves are estimated to last for another 40-45 years. To meet the 778 GW demand for power by 2031-

32, the Government of India is planning heavy investments in coal based power generation, where cost of production is lower than with any other source. Coal based power is grid connected which leads to major power related issue in India namely AT&C (aggregated technical & commercial) losses ranging from 18-62 % across Indian states, losses due to theft and pilferage about INR 20000 crore(1 crore= 10000000) and poor billing and collection efficiency of around 55 % and 41 % respectively (Indian Semiconductor Association,2010)

In India in the past the electricity sector has always confined to centralized electricity planning with large component of thermal power generation from fossil fuels and mainly dominated by coal. However evidence has shown that this centralized planning has not been able to keep the balance between demand and supply at the moment. Centralized electricity generation has resulted in inequities, external debate, and environmental degradation due to supply limitations which can be seen from the fact that still near by 70% of Indian population live in rural areas and around 40% of total population lives without any modern energy services. A huge portion of Indian population depends on state distributed and subsidized kerosene, animal and human energy, candles and biomass including cow dung and [3] (APCTT-UNESCAP, 2009; Bhattacharyya, 2010; Deshmukh et al, 2010; Patni, 2009; White, 2009)

Although the government has initiated distributed generation (turbines and micro-turbines, renewables, hybrids typically in the range of 1 kW to 50MW that can be combined with energy management and storage systems and used to improve the operations of the electricity delivery systems at or near the end user) and mini grid power plants for community welfare plants they are still constrained by factors such as limited power supply, low load factor, limited opportunities for innovative financing, and other market based business approaches. In rural electrification schemes by government a village has been deemed electrified if a mere 10 percent of households has electricity and earlier rural electrification was just considered as the installation of a pump in the village. [4] A common villager may need to wait for 20 years for government schemes to work. Many government initiatives have also been criticized for being too ambitious, supporting large players and not understanding the needs of rural population. [5]

Apart from problems of rural electrification a large section of urban India still faces problems related to lack of energy services. There is a significant challenge in terms of providing access of clean energy to a large section of population in urban areas. Kerosene and electricity are the major fuels used for lighting in rural and urban areas. Although 56% of Indian households use electricity for lighting, the urban rural disparity is prominent. About 43.5% of rural households have access to electricity while the rest rely mostly on kerosene. In contract about 87.6 % of the urban households use electricity for lighting and about 11.6% use kerosene. Besides focusing on a minor energy need, rural electrification also places sole emphasis on rural households and neglects urban population lacking access to electricity. As mentioned earlier around 7 million urban households suffer from this while around 16 million rely on traditional energies for cooking. There is no specific programme to cater to their needs. The problem of urban poor can be expected to aggravate with growth in urbanization and ignoring or forgetting these people can be a source of major future problem (Bhattacharya, 2006; Bhattacharyya, 2010).

Resulting from these observations we suggest that rural as well as urban energy systems must be economically efficient, needs oriented, equitable, empowering and environmentally sound for electrification to be developmentally and environmentally sustainable. This puts a lot of pressure not only on the design and establishment of new electricity options but also on the underlying conditions shaping the context for rural electrification. With regard to the Indian context achievements of electrification for rural and urban poor to date are rather dismal with rising transmission and distribution losses and

[3] http://www.iea.org/country/country_subform.asp
[4] http://ipsnews.net/news.asp?idnews=40568
[5] http://www.renewableenergyworld.com/rea/news/article/2009/12/solar-india-bold-plan-or-bargaining-ploy

declining cost recovery. Given the scarcity of non renewable resources and the shortcomings of conventional electrification, the potential of renewable energy sources for rural energy supply is very necessary.

Advantageous conditions for applying renewable energy options arise due to the vast geographical extension of the areas to be electrified, the dispersed and scarce settlement structures and the costly and inefficient transmission losses. Furthermore renewable energy options can be oriented towards concrete local demands and usages (Benecke, 2008).In this respect we would like to discuss the potential of renewable energy technologies specially PV technology in India.

## 1.4 Renewable energy in India

At present, renewable energy accounts for about 11% of India's installed generation capacity of 152 GW. Much of this capacity is wind-based (about 11 GW) with the share of solar power being only about 6 MW which can be seen in Table 1.1 below.

**Table 1.1:** Cumulative installed base of various renewable energy technologies in India (Mw) (Source: Indian Semiconductor Association, 2010)

| No. | Sources / Systems | Achievements during 2009-10 (up to 31.12.2009) | Cumulative achievements (up to 31.12.2009) |
|---|---|---|---|
| **I. Power From renewable** | | | |
| **A. Grid-interactive renewable power** | | | |
| 1. | Biomass power (Agro residues) | 131.50 MW | 834.50 MW |
| 2. | Wind power | 683.00 MW | 10925.00 MW |
| 3. | Small hydro power (up to 25 MW) | 129.15 MW | 2558.92 MW |
| 4. | Cogeneration-bagasse | 253.00 MW | 1302.00 MW |
| 5. | Waste to energy | 4.72 MW | 65.01 MW |
| 6. | Solar power | 3.10 MW | 6.00 MW |
| | **Subtotal (in MW) (A)** | **1204.47 MW** | **15691.43 MW** |
| **B. Off-Grid/distributed renewable power (including Captive/CHP Plants)** | | | |
| 7 | Biomass power / cogen.(non-bagasse) | 39.80 MW | 210.57 MW |
| 8. | Biomass gasifier | 4.10 MWeq. | 109.62 MWeq |
| 9. | Waste-to- Energy | 3.91 MWeq. | 37.97 MWeq |
| 10. | Solar PV power plants and street lights | 0.086 MWp | 2.39 MWp |
| 11. | Aero-generators/hybrid systems | MW | 0.89 MW |
| | **Subtotal (B)** | **47.876 MWeq** | **361.44 MWeq** |
| | **Total ( A + B )** | **1252.346 MW** | **16052.87 MW** |
| **II.** | **Remote village electrification** | 700 Villages & Hamlets | 4997 villages / 1257 hamlets |

## 1.5 Potential of PV technology in India

With respect to the geographical location India has a lot of advantages in terms of becoming a solar nation. The annual global solar radiation incident over India ranges from 1200 to 2300 kWh/m2 with most of the country having radiation greater than 1900 kWh/m2/year with about 300 clear sunny days. India's solar radiation is higher than countries like Germany where annual solar radiation ranges from 800 kWh/m2 to 1200 kWh/m2. Among other renewable sources of electricity generation, wind has seen rapid growth in India in recent years. However India being a medium wind profile country, its low plant load factors and the saturation of optimal locations for wind generation are expected make it less attractive than PV in the longer term (Banerjee et al, 2009; Prasad, 2009).

In India the Government (railways, telecom, defense etc) have been the largest consumers of solar energy in India. (Banerjee et al, 2009; Chaurey, 2008; Jawahar Lal Nehru National Solar mission, 2009; Prasad, 2009; Price water house Coopers, 2010). Currently PV installations in India, almost entirely consist of off grid connectivity and small capacity applications, used mostly for public lighting, such as street lighting, traffic lighting, and domestic power back up in urban areas and small electrification systems and solar lanterns in the rural areas. In recent years, it is also being used for powering water pumps for farming and small industrial areas. In India decentralized PV systems for rural electrification continue to hold relevance at local levels on account of the key challenges of ensuring energy security to all communities, as well as at the global level on account of climate change concerns and meeting the MDGs including education, health, environment protection and livelihood generation (Chaurey et al,2010). The installed base of various solar energy technologies is shown below.

**Table 1.2:** Installed base of various solar energy applications in India (1 Lakh= 100000)
(Source: Indian semiconductor association, 2010)

| Product | Installed base |
|---|---|
| Solar lanterns | 7.67 lakh units |
| Home lighting systems | 5.1 lakh units |
| SPV pumps | 7,247 units |
| Solar water heating | 3.25 mn sq mtr (collection area) |
| Solar cookers | 6.72 lakh units |
| SPV Street Lighting | 82,384 nos. |

With respect to the figures in Table 1.2 we see that although India has a vast opportunity for PV technology the performance in terms of installed base for various solar energy technologies has not been satisfactory. Solar energy technologies have been deployed more in sectors such as telecom, railway and international projects. Nor the performance in terms of grid based plants been good which could reduce India’s dependence on coal based electricity. In this respect we would like to focus on how PV technology can be commercialized and up scaled to serve dual purposes i.e. providing energy services to a large section of population which lacks access to modern energy services as well as reducing green house gas emissions.

A robust and expanding PV industry in India has the potential to create jobs right across the value chain from specialized high paying, high technology sector employment in R&D to employment for manufacturing workers, technicians, construction workers, installers and in field maintenance. Wide PV adoption is also likely to produce a whole host of opportunities for smaller businesses and entrepreneurs across the country in the sales, service and maintenance of PV systems including in the Balance of Systems (BOS) i.e. supply chain spanning charge control/inverter electronics and battery systems (PV group, 2009). This leads to the research questions and sub questions.

## 1.6 Research question and sub questions

Previous studies Balachandra et al (2010); Chai et al (2010) ; Ghosh et al (2006); Hendry et al (2009) ; Lund (2010); Neij (1997); Payne et al (2005); Purohit et al (2010); Reddy et al (2004) on commercialization of sustainable energy technologies have focused more on techno economic studies on successful commercialization and upscaling. The analysis therefore has not lead to an improved understanding of dynamics of processes involved in commercializing sustainable energy technologies.

New technologies may initially have low performance which may reduce market viability. Subsequent technical improvement, the development of a new body of technical knowledge and its translation into design rules, technical specifications, models, and rules of thumb often takes a long time. Markets, user preferences, and user competences may thus need to be co constructed with new technologies. A broader socio technical context may need to be taken into account in which new technologies can function. This may entail the creation of new infrastructures, complementary technologies, symbolic meaning, industry structures, subsidies, and support programmes and appropriate regulations. Furthermore various types of actors (including among many others, producers and users of knowledge and technology) and institutions (that define the rules and regulations shaping the behaviour of actors) influence the development and implementation of the new technology. The technological developments in turn shape the behaviour of the actors and the institutional setting. Thus the development and implementation of new technologies can best be understood as a highly complex process in which technological change and social change interact and mutually influence each other (Meijer, 2008; Raven et al, 2010).

Based on science and technology and innovation studies the multi level perspective (MLP) and strategic niche management (SNM) [6]can lead to insights for system innovations in which experiments (Planned initiatives which embody a highly novel socio technical configuration which is likely to lead to substantial sustainability gains) and niches (a coherent set of rules and institutions that enables and constrains the choices and behaviour of regime actors including firms, users, policy actors, scientists, etc and the selection environment for innovations) can upscale and transform the dominant socio technical regime [7] (Berkhout et al, 2010; Raven et al, 2010) .

There are already a large a number of sustainability experiments being carried out in developing nations like India and are very important for learning processes towards sustainability. However currently little is known about up scaling processes as to how different experiments such as demonstration and pilot projects, social enterprises etc can scale since the current initiatives may remain at pilot stages and may not destabilize the existing regimes. Thus it is crucial to understand how experiments can niches can up scale. At the same time since there is also lack of understanding of different barriers, dimensions and mechanisms through which they can upscale. Policy makers and practitioners therefore need concrete methodologies as to how they can develop adequate strategies and policies to meet these challenges in a systematic way which focus on dynamics of socio technical systems.

Another critical challenge is the idea of convergence of the sustainability agenda with other policy agenda's and especially agendas related to economic growth, poverty reduction and job creation in developing nations. Sustainability issues only make a chance of widespread acceptance in developing economies when they converge rather than compete with these agendas. Furthermore there is also a

[6] More detailed description of the literature in Chapter 2

[7] Please look at chapter 3 i.e. section of methodology about how distinction between experiments, niche ,regime etc is made operational for the research

transnational dimension to transitions and upscaling of experiments and niches since the developing nations depend to a large extent on the developed nations for access to knowledge about emerging renewable energy technologies (Berkhout et al, 2010; Raven et al, 2010). Based on these insights we formulate the following research question and sub questions.

**Research question: How has the PV niche developed in India and what are the different dimensions and mechanisms through which it can upscale and transform the dominant sociotechnical energy regime?**

**Sub questions**

**Methodological questions**

1. How can we synthesize insights from different streams of literature to formulate and develop scientifically grounded framework to understand upscaling of niche and experiments in PV solar energy in context of developing countries such as India?

2. What are the different barriers to successful upscaling of niches and experiments and the dimensions and mechanisms through which niches and experiments can upscale?

3.How can we link upscaling of niche (meso level) to upscaling of experiments (micro level)?

4.How suitable is the theoretical framework developed for understanding upscaling of niche and experiments?

**Empirical questions**

5. What kind of insights can be gained from the theoretical framework developed and findings obtained from analysis of upscaling of niche and experiments in India?

**Policy questions**

6. Which current and future policy mechanisms are needed in order to address dual challenges of sustainability as well as poverty reduction, job creation and economic growth through upscaling of niche and experiments specially in context of developing countries like India?

Thus the central aim of this thesis is to gain a better understanding of the different dimensions and mechanism through which niche and experiments can be up scaled leading to transformation of the dominant socio technical regime and various policy mechanisms needed to up scale them.

### 1.7 Research justification

Here we discuss the societal, scientific and policy relevance of the study.

Societal relevance

Energy provision through sustainable energy technologies like PV can meet the energy needs of large numbers of people in India and also contribute to reduction of green house gases. An understanding of how PV technology can commercialize will also lead to development of new sectors and sub sectors and also lead to economic development and creation of green jobs.

Scientific relevance

Currently the transitions studies framework lack insights into phenomenon of up scaling of experiments and niches particularly in developing nations (Raven et al, 2010).This thesis tries to fill this gap by answering the research questions. It also tries to bring new theoretical insights into the transitions literature from other streams of literature to develop mechanism for up scaling of experiments and niche in the context of emerging nations like India.

Policy relevance

Currently the policy mechanism being used for commercialization of sustainable energy technologies in developing countries like India are dominated by technological and economic approaches. However there is a need for developing policy mechanism which not only take technology and markets but also infrastructure, cultural aspects, consumer behavior, societal institutions i.e. focus on socio technical systems which pay attentions to co evolution (Between technology and users; technology, industry structure and policy institutions; science, technology and the market; science and technology ; technology and culture ; artefacts, beliefs (of designers) and evaluation routines and technology and society).This thesis may help policy makers in designing effective policies which focus on transformation of existing socio technical regimes.

## 1.8 Boundaries of research

This research will focus on how PV technology can make a significant contribution towards meeting energy needs of the poor as well as contribute towards sustainable development in India as well as globally. Therefore we discuss both the role of grid based as well as off grid applications. Large scale PV electrification projects can be useful for reducing green house gas emissions whereas off grid PV applications could be a option for meeting energy needs of poor with specific end uses in mind. In case of meeting the energy needs of poor through off grid PV applications the emphasis will be more on electricity and lighting needs and not on thermal and mechanical energy needs.

However this does not mean that PV technology is the only technology which can help us in achieving goals of energy poverty reduction as well as sustainability. Though PV technology has certain benefits which may be exaggerated, a range of sustainable energy technologies need to be pursued rather than locking into PV technology alone. A technology neutral approach would be the ideal approach. However due to the limitations of this research we cannot discuss commercialization strategies for all renewable energy technologies as it requires a detailed analysis and we limit to PV technology alone.

In the thesis we focus more on dimensions of upscaling and mechanisms(how can it done) for up scaling and less on barriers to up scaling due to the complex and multifaceted process of up scaling. Furthermore it is quite difficult to point out all kinds of different dimensions, mechanisms and barriers and we will focus on the most important and relevant barriers, mechanism and dimensions based on a thorough literature review.

## 1.9 Structure and outline of the thesis

This thesis is structured as follows

The first chapter introduced and contextualized the research and the research questions and justified the choice of topic and problem. Chapter two presents the theoretical framework for the research. In chapter 2 we develop the theoretical framework by combining insights from different streams of literature. In chapter three we discuss the research methodlogy.Chapter four and chapter five discuss upscaling of on grid and off grid PV technology by using the theoretical framework developed in chapter two and methodology presented in chapter three. Chapter six discusses the conclusion, theoretical contributions and summary of the research and chapter seven presents methodological reflections and policy recommendations. A lot of analysis from chapter four and five has been shifted to the appendix due to space constraints. For readers interested in detailed analysis appendix A and appendix B are highly recommended.

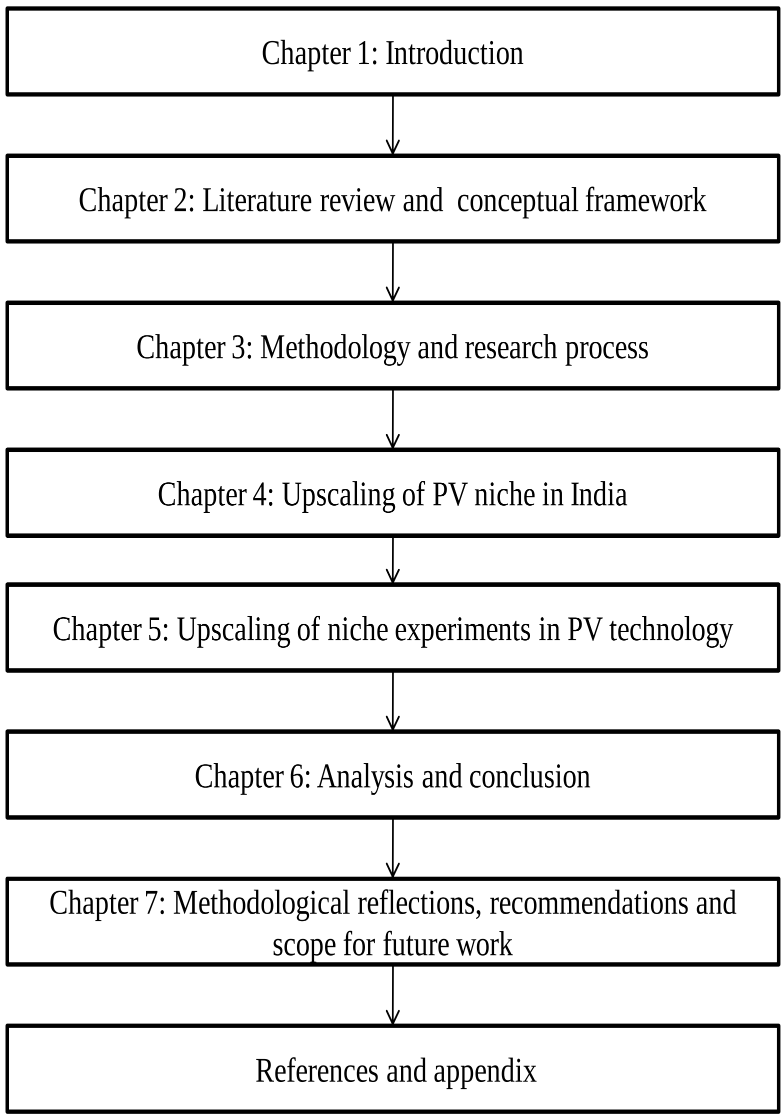


**Figure 1.3:** Structure and outline of the thesis

# Chapter 2: Literature review and conceptual framework

## 2.1 Systems innovation and sustainability transitions

The energy sector is subject to various forces of change. The existing energy system is strongly dependent on fossil fuels such as oil, natural gas and coal. In order to counteract these environmental problems and achieve a more sustainable future a major transformation of the energy sector is needed. To create a sustainable energy system, new technologies which are more sustainable than the existing technologies need to be developed and implemented on a large scale. To accelerate the transition to a more sustainable energy system, it is important to understand how more sustainable energy technologies are developed and implemented and which factors influence this process. However success of new and more sustainable energy technologies is not only determined by technical and economic factors but also by social system in which these energy technologies are embedded. Various types of actors including among many others, producers and users of knowledge and technology) and institutions (that define the rules and regulations shaping the behaviour of actors) influence the development and implementation of the new technology. Thus the development and implementation of new technologies can best be understood as a highly complex process in which technological change and social change interact and mutually influence each other and may involve developments in different domains such as economy, technology and politics. The terms transitions and socio technical transformation have been used to describe these long term transformations (Meijer, 2008).

Transitions involve a change in the socio technical systems. The concept of socio technical system denotes a relatively stable configuration of techniques and artifacts as well as institutions, rules, practices and networks that determine the dormant developments and use of technologies in a particular area of human needs and socially valued functions like provision of electricity (Vergragt et al, 2008). A system innovation can be understood as a change from one socio technical system to another. One aspect of a system innovation is technological substitution which comprises three sub-processes namely emergence of new technologies, diffusion of new technologies and replacement of old by new technology. System innovations not only involve technological substitutions but also changes in elements such as user practices, regulation, industrial networks, infrastructure, and cultural meaning (Geels, 2005).Transitions are also a multi actor process i.e. involving a wide range of actors, including firms, consumers, NGOs, knowledge producers and governments; multi factor i.e. result from the interplay of many factors that influence each other like technical, regulatory, societal behavioural change (Elzen et al, 2005). The system innovation literature makes wide use of a multi-level perspective as a heuristic tool to trace and understand major structural changes (called transitions) in socio-technical systems. The multi level perspective has been developed for explaining transition process.

### Multi level perspective

The Multi Level Perspective (MLP) aims to understand major socio technical change by conceptualising transformations as the result of processes occurring at and between three inter-related levels: niches, regimes and landscape. The multi level concept distinguishes between three levels of heuristic analytical concept namely socio technical niches, socio technical regime and socio technical niches. The three levels are distinguished and are not ontological descriptions of ‘reality’ but analytical and heuristic concepts to understand the complex dynamics of socio technical change. The logic of the three levels is that they provide different kinds of structuration of activities in local practices. The nested character of these levels means that regimes are embedded within landscapes and niches within regimes. This is also shown in the figure below.

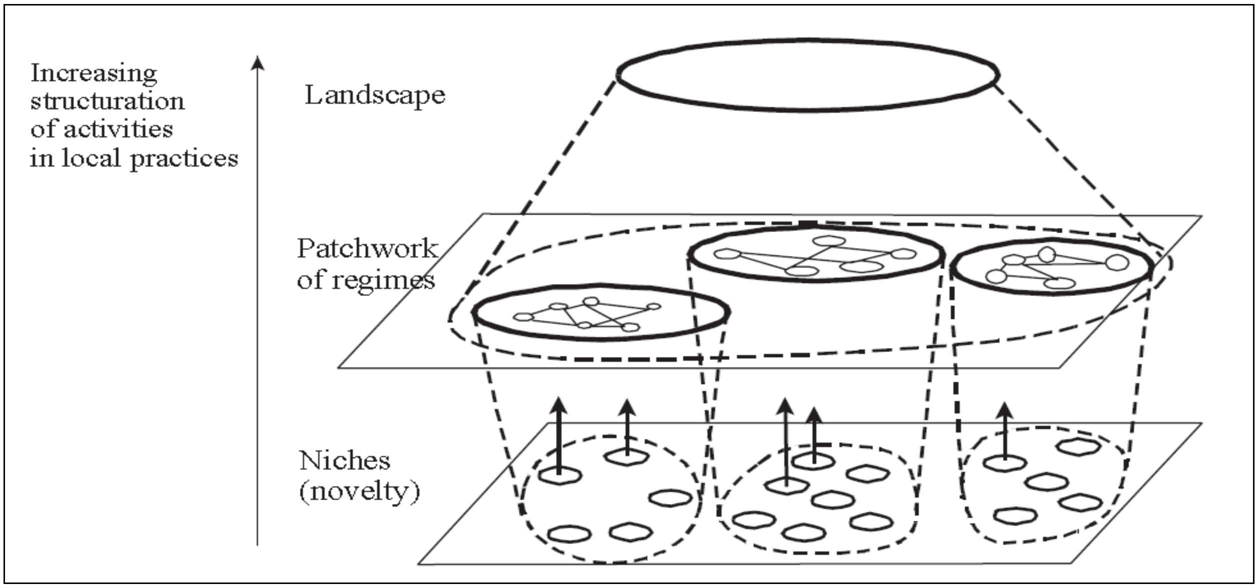


**Figure.2.1 :** Multi Level Perspective (Source: Geels, 2005)

Technological niches form the micro level where radical novelties emerge. Niches act as incubation rooms protecting novelties against mainstream market selection. Niche innovations are carried and developed by small networks of dedicated actors often outsiders or fringe actors in relation to the regime actors. While regimes generate incremental innovations, radical innovations are generated in niches.

The socio technical landscape highlights the technical, physical and material backdrop that sustains society. It contains a set of heterogeneous, slow changing factors such as cultural and normative values, demographic, political and international developments, broad political coalitions, long-term economic developments, accumulating environmental problems growth, emigration. Socio technical landscape can also generate shocks and surprises such as wars, rapidly rising oil prices .The main point is that the landscape is an external context for actors in niches and regimes. Landscape factors can be a source of pressure on regime and form the macro level of social and technological change. While regimes can be changed to some extent by actors in the regime it is more difficult to change landscape factors.

The multi level perspective argues that transitions come about through interactions between processes at these three levels i.e. niche innovations build up internal momentum through learning processes, price/performance improvements and support from powerful groups. Changes at the landscape level create pressure on the regime and destabilization of the regime creates windows of opportunity for niche innovations (Geels, 2002; Geels, 2005; Raven et al, 2010).

The concept of Multi Level Perspective was further improved by Geels et al (2007) as shown in the diagram. One important conceptual addition was made i.e. perceptions of niche actors and size of support networks are influenced by broader regime and landscape developments simultaneously.

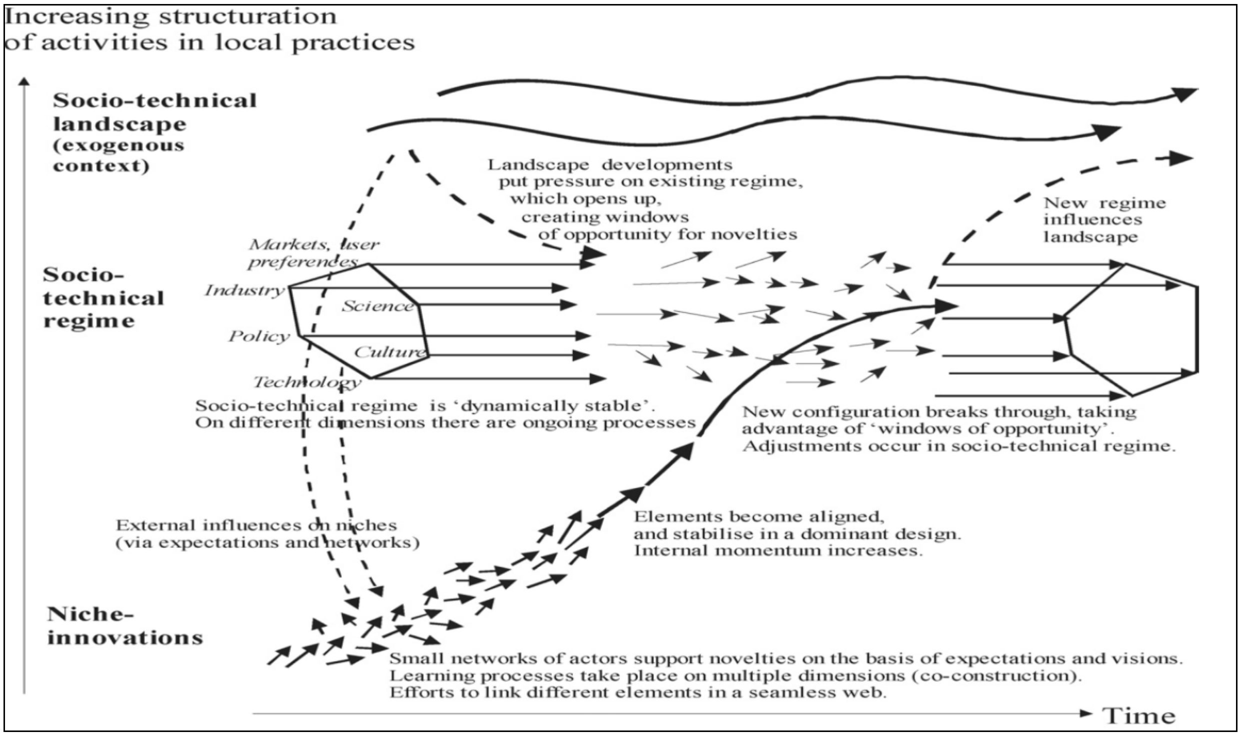


**Figure 2.2:** Multi Level Perspective on transition (Source: Geels et al, 2007)

Some important factors for niche transformation are powerful actors in the support network being improved strong expectations of further improvement (e.g. learning curves); and the innovation is used in market niches. Another important condition is i.e. timing of landscape pressure on regimes with regard to niche developments. Particularly important is the timing of landscape pressure on regimes with regard to the state of niche-developments. If landscape pressure occurs at a time when niche-innovations are not yet fully developed, the transition path will be different from what it would be than when they are fully developed (Geels et al, 2007).

## 2.2 Strategic Niche Management

Radically new and sustainable technologies often remain on shelf do not commercialize give rise to specific managerial problems and often meet resistance from vested interests. The Strategic Niche Management theory was developed from evolutionary theories of technical change, science technology studies, evolutionary economics and institutional theories in 1990's. Strategic Niche Management is defined as creation, development and controlled phase out of protected spaces for the development and use of promising technologies by means of experimentation with aim of learning about desirability of new technology and enhancing further development of technology by also making institutional adaptations and stimulating learning processes for further development of technology. Experiments are a crucial part of SNM. Experiments are a way to stimulate articulation processes that are necessary for the new technology to become socially embedded (Kemp et al, 1998).

According to Berkhout et al (2010) sustainability experiments can be defined as planned initiatives that embody a highly novel socio technical configuration which is likely to lead to substantial sustainability gains. Experiments represent small initiatives in which the earliest stages of a process of socio technical learning takes place. Experiments typically bring together new networks of actors with knowledge, capabilities and resources, cooperating in a process of learning. These can include a wide range of projects, pilot plants and demonstration facilities initiated by firms, public research organisations and universities, community and grassroots organisations and so on.

Technological niches are special application domains that are protected from some of the rules in the regime e.g. price/performance ratio, user preferences or regulatory requirements. Protection for instance, subsidies or regulatory exemptions from the technological regime can create a proto (temporary) market that provides a testing ground for novel technologies. A technological niche facilitates learning and improves societal embedding; technologies may improve or new functionalities may emerge. In Strategic Niche Management technological niches are the breeding place for radical innovation. On the other hand market niches are application domains in which a new technology has some specific advantages over the established technology, with both producers and users of the technology acknowledging this fact. Further development and diffusion (e.g. through application of the technology in new niches) can eventually result in a transition, or in a regime shift: the previous basic set of rules has changed into a new basic set of rules (Raven, 2005). This pattern is also shown in the diagram below

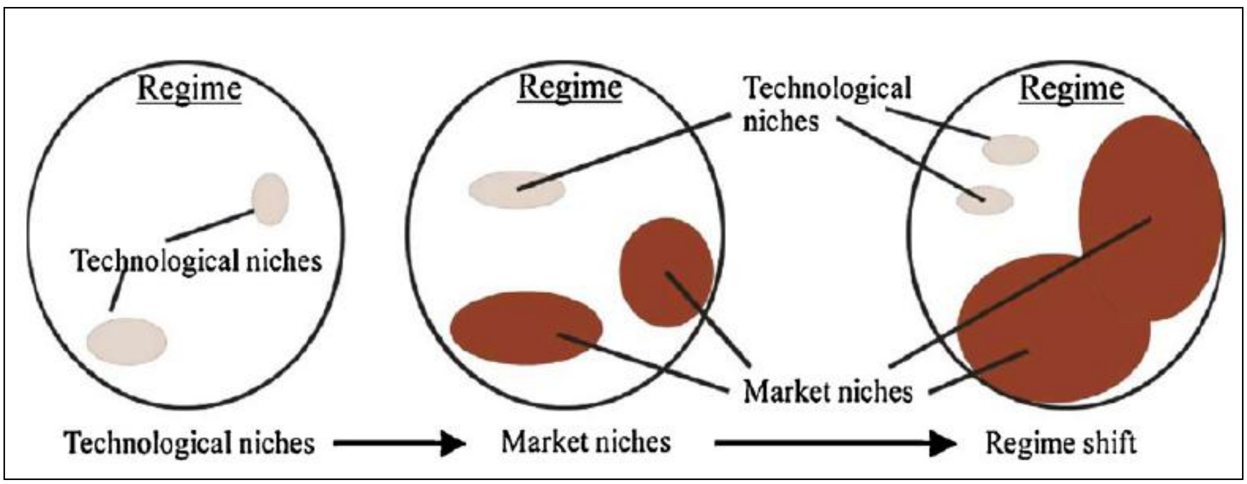


**Figure 2.3:** From technological niches to market niches to regime shift (Source: Verbong et al, 2010)

A niche can be considered as a space or location for actors to develop an innovation, micro level of technological and social change, series of experimental projects such as demonstration projects and pilot plants, constellation of structures, cultures and practices which transform the way in which social needs are met. Niches can also be considered a loosely defined set of formal and informal rules for new technological practice, explored in societal experiments and protected by a relative small network of industries, users, researchers, policy makers and other involved actors. Over time niches may develop increasingly stable rules, and their relation to regimes may change. However in principle niches and regimes are similar kinds of structures, but niches are characterized by unstable and less developed sets of rules and smaller networks (Geels et al, 2007; Raven, 2005; Raven, 2010).

Smith (2003) further classifies two sets of lessons for niches i.e. lessons internal to the niche and external to niche. Lessons internal to niche include lessons about the technical and economical feasibility and environmental gains of different technological options and participation in the niche from a wide set of actors (eg state policy makers, regulatory agency, local authorities, development agency, non governmental organizations, citizen group, private company, industry organization, special interest group) including participation of outside actors. Lessons external to niche include looking for policy and institutional reforms by articulating changes in technology and institutional framework surrounding it as well as building a constituency behind a technology in terms of firms, researchers, public authorities as their actions are also needed for mainstreaming of the technology.

Strategic Niche Management focuses on three main processes i.e. coupling of expectations, articulation and learning process and network formation. By coupling of expectations it is meant that in order to map the new technology, the interested actors therefore make promises and raise expectations about new technologies.Articulating expectations about sustainable futures serves as a rationale for acquiring resources, help reduce uncertainty and once shared and transformed into agenda's, they can mobilise others. Expectations are particularly powerful when they are shared by large number of actors, specific enough for agenda setting and tangible in nature. Shaping new social networks is considered a prerequisite for successful transitions and is required to sustain the niche, provide resources, conduct experiments, carry and articulate expectations and organise and participate in learning processes. Two characteristics of social networks are important for constructing niches i.e. heterogeneity including actors from both industry,research,research organizations, users, policy makers and NGO's and presence of outside actors such as innovative new firms, academic professionals and societal pressures.

Successful learning is considered the primary process for the development of sustainability niches. In fact, expectations and social networks must be designed in ways to optimise the learning process.SNM proposes to broaden learning beyond techno economic optimization and also focussing on other dimensions like regulations, cultural meaning, user preferences etc. By taking insights from organizational learning is also conceptualized by single loop learning i.e. getting things right and second loop learning i.e. are we doing the right things. Double loop learning is broad focusing not only on techno economic optimization but also on alignment between the technical (e.g. technical design, infrastructure) and the social (e.g. user preferences, regulation and cultural meaning) (Raven et al, 2009; Raven et al,2010).

**Protection mechanism**

The concept of protection is very important in Strategic Niche Management. The protection is needed because new technologies initially may be expensive, unreliable and not yet aligned with user preferences, practices and expectations. Protection mechanism can be useful in making up for the short term poor performance with the hope of long term economic and environmental benefits. Typically experiments are given some protection from normal selection pressures in the market. This protection may be achieved within the private sector through investments of risk capital, through public policies such as subsidies, investments or through some combination of both. Protection can be in many forms such as economic protection (e.g. subsidies and price measures); institutional protection (e.g. modified regulations, preferential grid access); socio cognitive protection (e.g. activities by research institutes, training programmes); cultural protection (e.g. community energy ambitions, iconic configurations for environmentalists); spatial protection (e.g. resource attributes, favourable local economic histories); and political protection (e.g. embodying a political programme, like eco-towns, effective low carbon leadership) (Berkhout et al, 2010; Smith et al, 2009; Ulmanen et al, 2009).

## 2.3 Niche regime interactions

Geels et al (2007); Geels et al ( 2008); Raven (2005); Raven et al ( 2009); Smith et al ( 2005); Smith et al (2007) emphasise that SNM approach has stressed too much on local experimentation in promising niches and promising bottom up experimentation . However sustainability transitions should not only be directed towards niche internal processes but also at destabilising prevailing regimes. The argument is that transformation of niches can mainly result from tensions and contradictions within the regime along with pressure from landscape. Thus there should be linkages between niches and regime.Rohracher (2008) suggests that actual picture is much more complex than what niche regime picture suggests. Regimes are linked to several other socio technical regimes and the separation of niche regime is also never clear cut.

Berkhout et al (2010); Elzen et al, (2008) discuss the concept of anchorage. In technological anchorage, novel technical artefacts, concepts and practices reach some stable configuration within a niche to the extent that they offer solutions to tensions and opportunities in the regimes and can become anchored there. Network anchorage refers to the broader acceptance of the concepts and practices emerging in a niche by actors outside the niche, who may also have positions within the established regime. Here hybrid and boundary spanning actors are held to be especially influential in helping to create new constituencies and advocacy coalitions in support of a transition. Institutional anchorage deals with changes in interpretive, normative and economic rules that take place as the new niche regime becomes further stabilized and embedded.

## 2.4 Upscaling of niches and experiments in systems of innovation literature

According to Weber et al (1999) upscaling is defined as transformation from level of experiment to level of technological niche or integrating a number of experiments and establishing technology on a larger scale. Some means for expanding an experiment into a niche are the dissemination of information, the extension of the network of actors and stakeholders, the involvement of competing parties in the network, the setting up of partner experiments or a modification of the regulatory and political framework facilitating the establishment of new and similar experiments.

Geels et al (2006); Raven et al (2010) define upscaling can be seen as transition from aggregation of local projects at local level to global niche level which are discussed in the next page. Further it can be said that the global niche level can also be compared to a technological niche where rules about the technology get established which can be used again for similar projects. This is also shown in the figure below

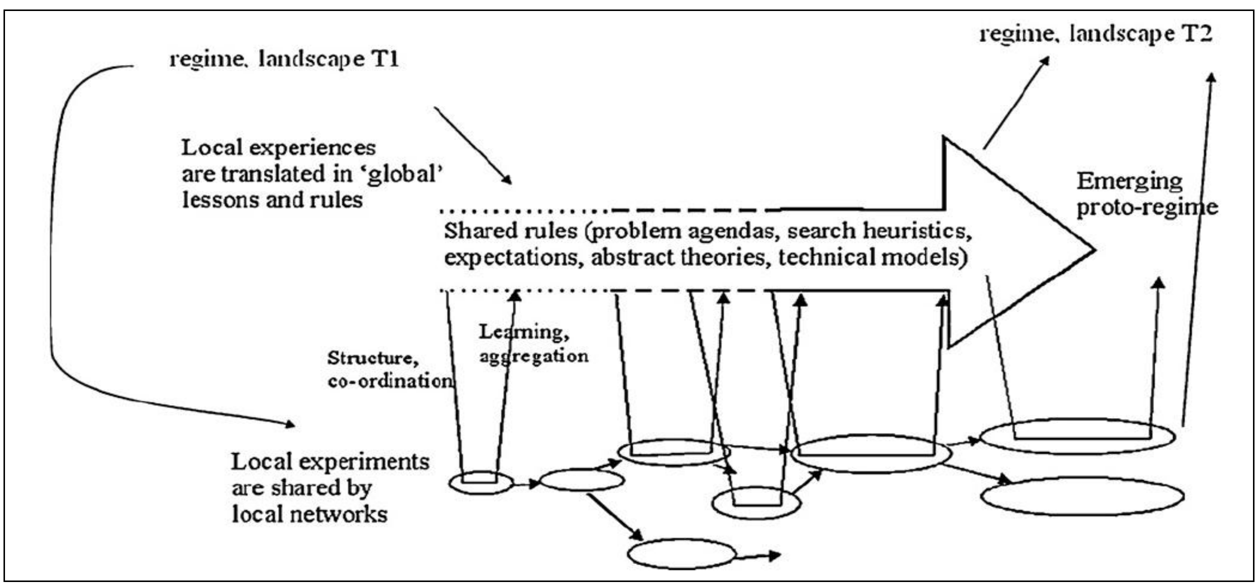


**Figure 2.4:** Distinction between local and global niche (Source: Raven et al, 2010)

According to Geels et al (2006); Raven et al (2009); Raven et al (2010) experiments are carried by variety of local networks generating knowledge which is location specific. The global niche refers to shared rules such as problem agendas, search abstracts, abstract models, shared expectations and visions as well as distinct networks that work to co ordinate flows of knowledge codify generic lessons and articulate field level agendas. The transformation of local outcomes into generic lessons and cognitive rules does not come automatically but requires dedicated aggregation activities, formalization and codification. Aggregation focuses on production of collective good and abstract knowledge that can be used by others. However due to free rider problems aggregation activities may not be evident. To solve these problems there is a need for creating intermediary organizations and actors like trade and industry associations, standardization organizations which are a part of the emerging community with collective interests. The aggregation process is shown in the figure below.

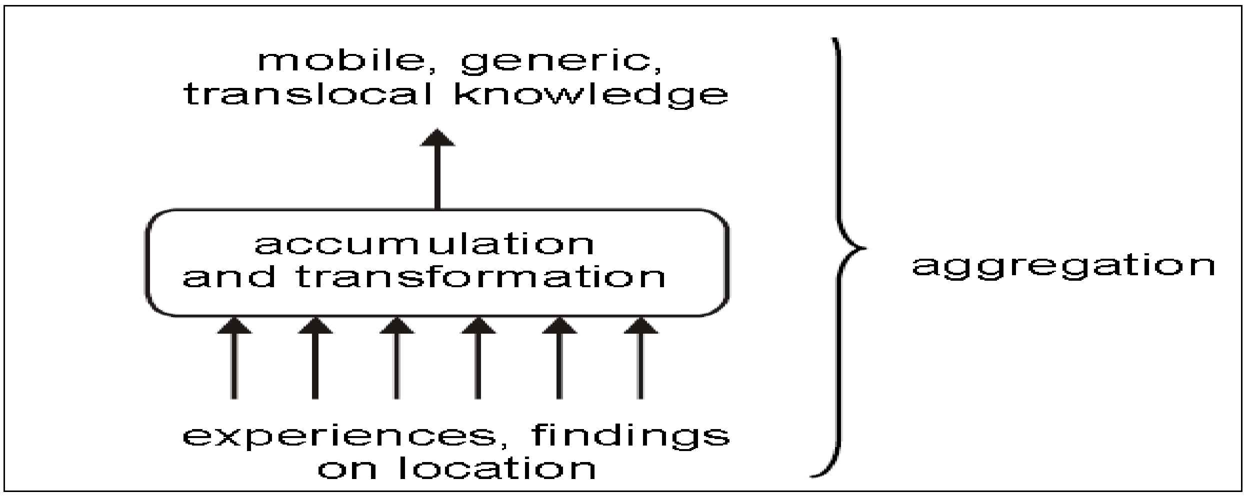


**Figure 2.5 :**Process of aggregation (Source:Geels,2006)

It is also stressed that intermediary actors such as professional societies and industry associations also stimulate and facilitate the production and circulation of technical knowledge. They may create technical standards, articulate problem agendas, and exchange experiences and findings to during workshops, meetings, research conferences, meetings arranged by intermediary organizations etc.

According to Van Lente et al (2003) there are three categories of organizations with an intermediary character i.e. Knowledge Intensive Business Services (KIBS) which act as support services , Research and Technology Organizations (RTOs) and a third group of semi public organizations or industry associations that are involved in policy related work including innovation centers, chambers of commerce, liaison offices, industry or trade associations. They also stress the importance of systemic intermediates which contribute towards leaning and experimentation in innovation systems.

Further Raven et al (2009); Rotmans et al (2008) also define upscaling in terms of transition from niche to regime which is not a single step but as a result of many intermediate steps. Scaling up occurs when transition experiments in niches eventually contribute to replacing the dominant regime structure, culture and practice as also discussed in the Multi Level Perspective. Some guiding principles for scaling up are stimulating institutional embedding, gaining structural support, involving key players from the regime and overcoming institutional barriers.

## 2.5 Transition Pathways

Perez (2004); Smith et al (2009) suggests that transformation process from old techno economic paradigm to new one causes mismatch within the socio institutional framework. During such periods institutions face a chaotic and unaccustomed situation which requires much deeper changes. There are no proven formulas and changes have to take place by trial and error experimentation under pressure of very high social costs of techno economic transformation. This also involves making very hard political choices about institutions and infrastructures.

Meijer et al (2008); Raven et al (2009) suggest that external regime and landscape developments can be predicted ex post but such predictions are hard to make ex ante. There are developments going on in multiple directions and any regime is influenced by hindering landscape developments making it hard to anticipate effects on niches. While landscape developments are certainly seen to influence both niche and regime dynamics it becomes extremely difficult to determine them ex ante.

To determine transition pathways ex ante Geels et al (2007) define four different transition pathways i.e. transformation, reconfiguration, technological substitution and de alignment and re alignment for transition to sustainable socio technical systems. They also mention that the transition pathways are not deterministic and there is no guarantee that new socio technical regime will emerge. The table below presents an overview of the four transition pathways.

**Table 2.1**: Typology of different transition pathways (Source: Elzen et al, 2007)

| Transition pathways | Main actors | Type of interaction | Characterisation |
|---|---|---|---|
| **1. Transformation** | Regime actors and outside groups (social movements) | Regime outsiders voice criticism. Incumbent regime actors adjust goals, guiding principles, search heuristics. | Outside pressure, institutional power struggles, negotiations, adjustment |
| **2. Technological substitution** | Incumbent firms versus new firms | Newcomers develop novelties, which compete with technologies from regime actors. | Market competition |
| **3. Reconfiguration** | Regime actors and suppliers | Regime actors adopt component-innovations, developed by new suppliers. Competition between old and new suppliers. | Cumulative component changes and new combinations |
| **4. De-alignment and re-alignment** | New niche actors | Incumbents lose faith and legitimacy. Emergence of many new actors, who compete for resources, attention and legitimacy. | Erosion, collapse, co-existence of multiple novelties, prolonged uncertainty, competition restabilisation |

According to Verbong et al (2010) the technological substitution pathway is less likely for infrastructural regimes as it is difficult to see complete replacement of the electricity or transport or telecommunication systems. In the transformation path the utilities focus more on constructing large scale offshore wind farms and large scale biomass gasification and combustion plants, coal or multi-fuel fired plants in combination with carbon capture and Storage (CCS) and nuclear power plants which fit well with the current existing regimes. Renewable energy technologies like PV, urban wind turbines, micro cogeneration remain confined to specific niches. Thus the nature of regimes plays an important role in stimulating or discouraging the niches. These niche innovations with highest probabilities for acceptance do not disrupt the basic architecture of the regime but stimulate reorientation in a more sustainable direction. In the reconfiguration pathway adoption of niche innovation may lead to gradual reconfiguration of the basic architecture of the regime with large scale renewable energy plants with the same top down philosophy which has been dominant with market mechanisms. This pathway takes a more balanced approach in terms of regimes incorporating niches. In the dealignment and re alignment pathway which focuses on distributed generation, experiments in niches can gradually take up the place of old incumbents leading to emergence of a new regime. This approach focuses on stimulating niche innovations which nurture emergence of a new system.

Similarly according to Foxon et al (2010) the governance patterns for transitions in future can be due to a mix and balance between actions from central government, market actors and grass root solutions. Transitions can be government led which is done by government departments, advisory bodies, regulatory bodies etc. They can also be led by market actors by private firms, electricity supply firms and smaller market based actors like emerging energy service companies. Further transitions can also be led by civil society actors like organized environmental and grass root organizations. Bottom up diverse solutions driven by innovative local bodies, citizen groups, locally based technological and institutional solutions can scale up and challenge the dominance of existing large energy companies.

## 2.6 Role of entrepreneurs and grass root solutions in sustainability transitions

In this respect we would like to discuss the role of such grass root initiatives and entrepreneurs and how they can upscale. In the Strategic Niche Management literature Kemp et al (1998) mention that "*Although our understanding of how technological transitions come about is limited, historical evidence suggests that entrepreneurs/system builders and niches play an important role in the transition process. The development of a new technological system is often associated with the names of entrepreneurs. For example, the names of Edison, Insull and Mitchell are associated with the development of the electric system*" (pp 183).Similarly Smith (2003); Smith (2007) also mention the role of entrepreneurs who can challenge the mainstream regime actors.

Previous research on development of sustainable energy systems and emergence of renewable energy have concentrated on system level innovation and regime shifts towards sustainability. These studies have thus focused more on development of system level policy drivers and regime barriers to clean energy technologies. However few studies have focused on how entrepreneurial firms or prime movers are important for such a system level transition (Teppo, 2006). Futhermore emerging renewable energy technologies cannot commercialize without involvement by entrepreneurs who dare to take actions aimed at developing and implementing emerging renewable energy technologies and commercialize them. Entrepreneurs have an important role in transition processes because of their potential in commercializing sustainable innovations and consequently bringing the necessary institutional change that favors such innovations since they are agents of 'creative destruction' (Keskin et al, 2009; Markard et al, 2008; Meijer et al, 2008).

Similarly according to Bergman et al ( 2010) ; Monaghan (2009); Seyfang et al( 2007); Seyfang et al (2010) the grassroots organizations have been another neglected area in the innovation literature. Innovation literature describes the important role of niches in seeding transformations in wider socio technological regimes. Grass root innovations, networks of activists and organizations have potential to generate novel bottom up solutions for sustainable development by responding to local situations and interests and values of the communities. In contrast to mainstream business greening grass root initiatives operate in civil society arenas and involve committed activists experimenting with social innovations as well as using greener technologies. They also have experience and knowledge about what works in their localities and what matters to local people. Bottom up social innovation can also play an important role in opposing the mainstream socio economic paradigm. However the main problem is that they do not to manage to grow beyond the initial pilot stage and also finding it difficult in replication, upscaling and mainstreaming of niche innovations to achieve systemic changes. According to Hockerts et al (2010); Ludeke (2008) sustainable entrepreneurship deals with economic, social and environmental value creation and sustainable entrepreneurs also play an important role in mainstreaming green innovations. Further appropriate business models for sustainability emanating from this domain may trigger development of niches and transformation of socio technical energy systems.

## 2.7 Social entrepreneurship

Another area which focuses on the role of entrepreneurs as key agents in transition processes is social entrepreneurship. Social entrepreneurship encompasses the activities and processes undertaken to discover, define and exploit opportunities in order to enhance social wealth by creating new ventures or managing existing organizations in an innovative manner. Social wealth may be defined broadly to include economic, societal, health and environmental aspects of human welfare. Social entrepreneurs may discover or create opportunities and launch ventures to make profit, create wealth or to balance social and economic incentives. They also create and develop the institutions and infrastructures needed for development (Dees, 2009; Mair et al, 2005; Seelos et al, 2005; Santos, 2010; Zahra et al, 2008; Zahra et al, 2009).

According to Raven et al (2009); Raven et al (2010); Witkamp (2008) social entrepreneurship is pitted against two regimes i.e. the business regime where profit maximization and increasing shareholder value is the major goal. On the other hand in the civil society regime social objectives take a major role and profit maximization takes a back seat. Social entrepreneurship therefore continuously faces tensions in terms of fulfilling social objectives and profit making. During the translation to regime some of the values in the niche may get jeopardized. Most social entrepreneurs have an ability to create new connections among people and organizations for new paths and for creating social value. However most social entrepreneurs face problems in terms of multiple value creation (social, financial, environmental), permeating into large bureaucracies such as regime players, and governments and convincing the institutional actors about them and their vision for a sustainable society.

According to Travaglini et al (2009) social enterprises can be classified into different categories ranging from traditional non profits to traditional for profit as shown in the figure below.

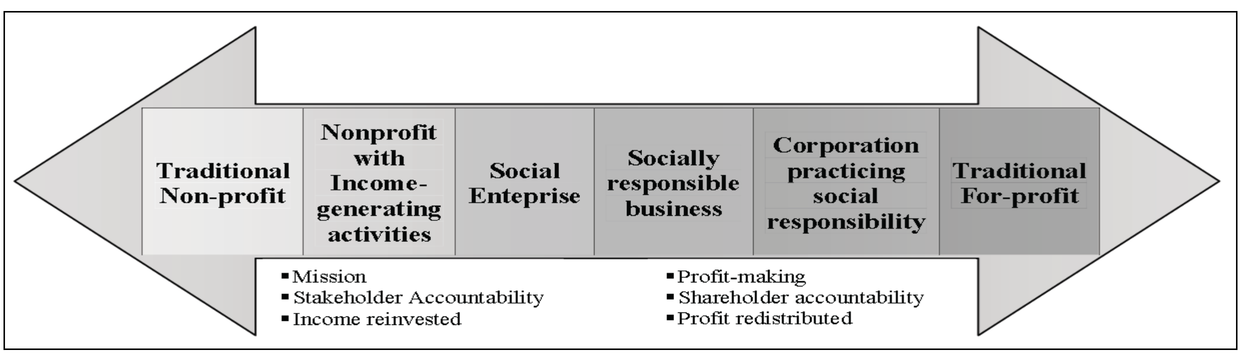


**Figure 2.6:** Hybrid spectrum of social enterprises (Source: Travaglini et al, 2009)

Thus different types of social enterprises adopt different ways to improve their social and economic value and their aims are also guided by different means. On the extreme left social enterprises look for creating social value and are often paid by donors or public and not directly from users. As one move from extreme left end enterprises look for more profit creation activities.

## 2.8 Upscaling of social enterprises

According to CASE (2006); Smith et al (2009) upscaling is defined as increasing the impact a social purpose organization produces to better match the magnitude of the social need or problem it seeks to address. Two major types of scaling can be distinguished i.e. scaling up and deep. Scaling up refers to the growth in social value by expanding a current program to other geographic locations. Scaling up to new regions or geographical scaling involves effort and costs in terms of building infrastructure, organize and developing an ecosystem, obtaining licenses, educating customers etc in a new region. In comparison to scaling up, scaling deep means focusing energies and resources on achieving greater impact in the same location where the enterprise was started by doing one of the following: improving the quality of services, achieving greater penetration of the target population, finding new ways to serve new people, extending services to new people and developing innovative financial management approaches. However scaling up or scaling deep is a matter of choice for the social entrepreneur.

Upscaling can also be referred to as the capacity of the enterprise to expand quickly, effectively and efficiently for the enterprise.Upscaling can also mean expanding the capacity of existing business (developing resources, building a knowledge base, employing people, management systems and even developing a culture). Upscaling can also be understood as serving more people with the same product within the same region as well as extending into new markets. However scaling to a large extent depends on the motivation of the enterprise. Some enterprises may focus on developing a specific region in terms of new products and services before scaling geographically while some may chose to scale into new geographies while venturing into new products and services later on (Karmachandani et al, 2009; Klein, 2008).

Another type of scaling is institutional scaling .This refers to entrepreneurs leading efforts to identify political opportunities, frame issues, and induce collective efforts to infuse new beliefs and norms into social structures. (Maguire et al,2004).Entrepreneurs can leverage resources to create new institutions or transform existing ones .There are a few examples like Grameen Bank and Sekem which were successful in catalyzing social change by altering long established norms and institutions (Mair et al, 2006; Robbin, 1984; Sud et al, 2008).

Yet another important kind of scaling is scaling of net impact. By net impact we mean improved education and livelihood for people, poverty reduction and reduction in green house gas emissions etc.The enterprise can focus on scaling this net social impact from its activities. However social enterprises may not have the robust enough systems to accurately assess how well they are helping the poor people or even contributing to sustainable development. They may judge success on basis of milestones achieved, amount of money invested, number of initiatives initiated rather than on how well their activities translate into changes on ground. [8] There is lack of techniques to monitor and evaluate social enterprises' financial and social mission achievement since traditionally social purpose organizations have typically been accorded significant levels of trust based on their stated objectives rather than their performance reporting (CASE, 2006; Lall, 2010; Mair et al, 2006; Nicholls, 2009; Yunus et al, 2010).

[8] http://hbr.org/2009/05/making-better-investments-at-the-base-of-the-pyramid/es

However in this respect there are some measurement techniques but they also are not easy to use. The impact value chain distinguishes between outputs, outcomes and impacts as measures of effectiveness. However the contribution of the social entrepreneur to social change is determined by specific positioning as there are other external factors influencing overall development, one also has to deduct the impacts of what would have happened anyway in order to obtain the specific contribution made by the social entrepreneur [9][10] (Achleitner, 2009; Clark, 2004; Lall, 2010; Maguire et al, 2004; Mair et al, 2006).

## 2.9 Framework for upscaling experiments and niches in developing nations

The objective is to develop a framework which can explain upscaling for new systems of innovation in the context of developing countries. According to Geels (2010) a framework encompasses many variables and seeks to capture much of the complexity and helps the analyst better think through the problem. Frameworks help to identify the relevant variables and the questions which the user must answer to order to develop conclusions tailored to particular industry and company. In addition all the interactions among the variables in the framework cannot be rigorously drawn. Van de Ven (1989) states that framework act as lenses filtering what we see and how do we interpret phenomenon. Thus a good framework can separate important issues from less important issues and help to define critical sub problems to deal with. Before suggesting a framework we would like to point out that there can be no systematic tools for understanding up scaling. The process of up scaling takes place at multiple dimensions and can mean different to different kinds of researchers and practitioners. In order to develop such a framework we need to combine and integrate insights from different streams of literature. We try to use an interdisciplinary research where we try to integrate different disciplines and streams of literature to develop a holistic view of the complex phenomenon of up scaling.

However there is a major problem with this kind of work. Each body of knowledge is developed and sustained by its own professional community, consisting of people who share a common body of knowledge and expertise. Researchers typically go it alone for solving a research problem without communicating with scholars from different fields, different functional expertise areas and practitioners with expertise. Each community research tends to be self reinforcing and insular and limited interactions occur between them. Researchers are also sometimes biased towards internal consistency and pay little attention to tensions and oppositions or contradictory thoughts. Further on going specializations in theoretical disciplines makes it difficult for researchers to comprehend the tensions facing practitioners in real life (Schultz et al, 2005; Van de Ven, 1989).

In this respect Geels (2010); Van de Ven (2007) mention that the goal should be to recognize different perspectives of knowledge as partial, incomplete and having inherent bias. A great deal can be learned from juxtaposing contradictory propositions and assumptions even if they are incompatible .Hence a pluralist and multidisciplinary approach of comparing multiple possible views of reality is essential for developing scientific knowledge.

There is a particular need for interdisciplinary research for addressing complex problems that are characterised by high levels of uncertainty. In contrast many argue that interdisciplinary collaboration to address pressing policy problems represents a dangerous erosion of the autonomy of science particularly given that disciplines have endured precisely because they serve many valuable functions. This can also lead to confusion over the conceptual nature of the interdisciplinary work. However interdisciplinary work can be more accountable to the society than disciplinary work which remains bounded within academic circles. Interdisciplinary research can also lead to new forms of academic practices which can destabilize existing disciplines and practices (Hargreaves et al, 2009).

[9] http://blog.acumenfund.org/author/khill/
[10] http://iris-standards.org/framework-overview

Here we try to explain upscaling which is a complex issue by bridging and integrating thoughts from multiple fields of literature as discussed. Thus we try to juxtapose concepts from system of innovation literature with lot of interrelated concepts in strategic management, social entrepreneurship, development studies, and Bottom of Pyramid literature. We suggest that by juxtaposing the different fields of research and by using a pluralist methodology we can generate interesting insights into complex phenomenon of up scaling. Based on the literature discussed so far and taking the context of developing nations into account we develop a specific framework suitable for up scaling of niches in developing nations specifically. Such a framework has to be contextualized keeping in mind the specific nature of developing nations.

There are many challenges in applying the theories of system innovation to socio technical regimes in developing countries are that regimes will tend to be less ordered and less stable than in developed countries. The actor networks are heterogeneous in composition; regimes and landscapes are relatively fluid rather than being stable; learning and technology diffusion between experiments, niches and regimes faces multiple institutional barriers and there is only limited understanding of how global knowledge linkages influence the development and growth of sustainability experiments. This may be because they are emerging in the context of higher rates of growth and compounded social, demographic and industrial transformations but also because the institutional and governance capacities in these countries are less settled and unstable (Berkhout, 2010).

The sustainability agenda in developing nations is also largely linked to other issues like economic growth, poverty reduction and provision of basic entities like electricity, water, food etc to a large section of population. Development of niches in developing nations is also likely to take place also takes place in an international context in terms of flow of knowledge and access to technologies and scientific knowledge and know how through global networks. Such transnational links may exist through direct or indirect relationships with foreign technical experts, overseas development assistance and foreign suppliers of technology. Although development of niches in developing nations are situated within global flows of knowledge and technology local capabilities, entrepreneurship and institutions also play a critical role (Bai et al, 2009; Berkhout et al, 2009; Raven et al, 2010; Verbong et al, 2010).

Another important point from Romijn et al (2008) [11] is that there is still a lack of understanding in SNM about the processes by which experiments can ultimately culminate in viable market niches that ultimately will contribute to a regime shift. Single SNM experiments are unlikely to lead to wider success unless they also entail the creation of entirely new sub sectors consisting of forwardly and backwardly linked economic activities, as well as the demise of older sub sectors that are replaced. As long as SNM experiments remain isolated activities without complementary experiments up and/or down the value chain, the critical mass needed to fuel these processes is very unlikely to develop. Based on these insights we try to develop a framework for up scaling of niche and experiments.

However there are several economic, social, political, organizational, institutional and several other factors which influence the development, diffusion and use of sustainable energy technologies. Entrepreneurs also operate in this system context and are influenced by its policies, regulations, interactions, norms, societal pressures etc in the system at the macro level. The literature which focuses on the transition towards sustainability has so far disregarded the interactions between entrepreneurs and the system context and insufficiently explains how innovation can act as a driver for sustainability. Therefore this calls for more research to strengthen between link between macro level of socio technical systems and micro level of entrepreneurial strategies (Woolthuis et al, 2009; Woolthuis et al, 2010).

[11] http://www.narcis.info/research/RecordID/OND1318361/Language/en

The different kinds of upscaling are defined now

**1.Upscaling of niches:** According to Raven (2010) a niche can be defined in several ways i.e.

1. A ‘space’ or ‘location’ that is protected from the dominant regime, which enables actors to develop and apply an innovation without immediate or direct pressure from existing regimes
2. The micro level of technological and social change
3. A new and relatively unstable set of rules and institutions for innovative practices
4. A series of experimental projects such as demonstration projects and pilot plants
5. A constellation of structures, culture and practices that deviates in the way social needs are fulfilled
6. The variation environment for radical innovations.

The upscaling which we discuss in the thesis assumes niche to be a loosely defined set of formal and informal rules for new technological practice, explored in societal experiments and protected by a relatively small network of industries, users, researchers, policy makers and other involved actors.

**2.Upscaling of experiments:** According to Berkhout et al (2010) sustainability experiments can be defined as planned initiatives that embody a highly novel socio technical configuration which is likely to lead to substantial sustainability gains. These can include a wide range of projects, pilot plants and demonstration facilities initiated by firms, public research organisations and universities, community and grassroots organisations and so on. In this thesis we define an experiment to be entrepreneurial solution i.e. social enterprise in the context of developing nations, which tries to meet the energy needs of the poor and reduce poverty by using emerging niche solutions such as PV.

Furthermore Up scaling is a process that involves both these levels and each cannot be studied in isolation .It is necessary to understand the processes at both levels i.e. niche and experiment and how they are interlinked. This is discussed later on in the thesis.

## 2.10 Upscaling of niches

This section describes how we develop a framework for up scaling of niches in terms of dimensions, mechanisms and empirical indicators.

According to Geels (2006) early in the development of a technology, there is much flux and uncertainty about precise technical characteristics, functional dimensions, markets and user preferences. Gradually, these dimensions become aligned and stabilize, leading to dominant designs and normal markets. The process is shown in the figure in next page.

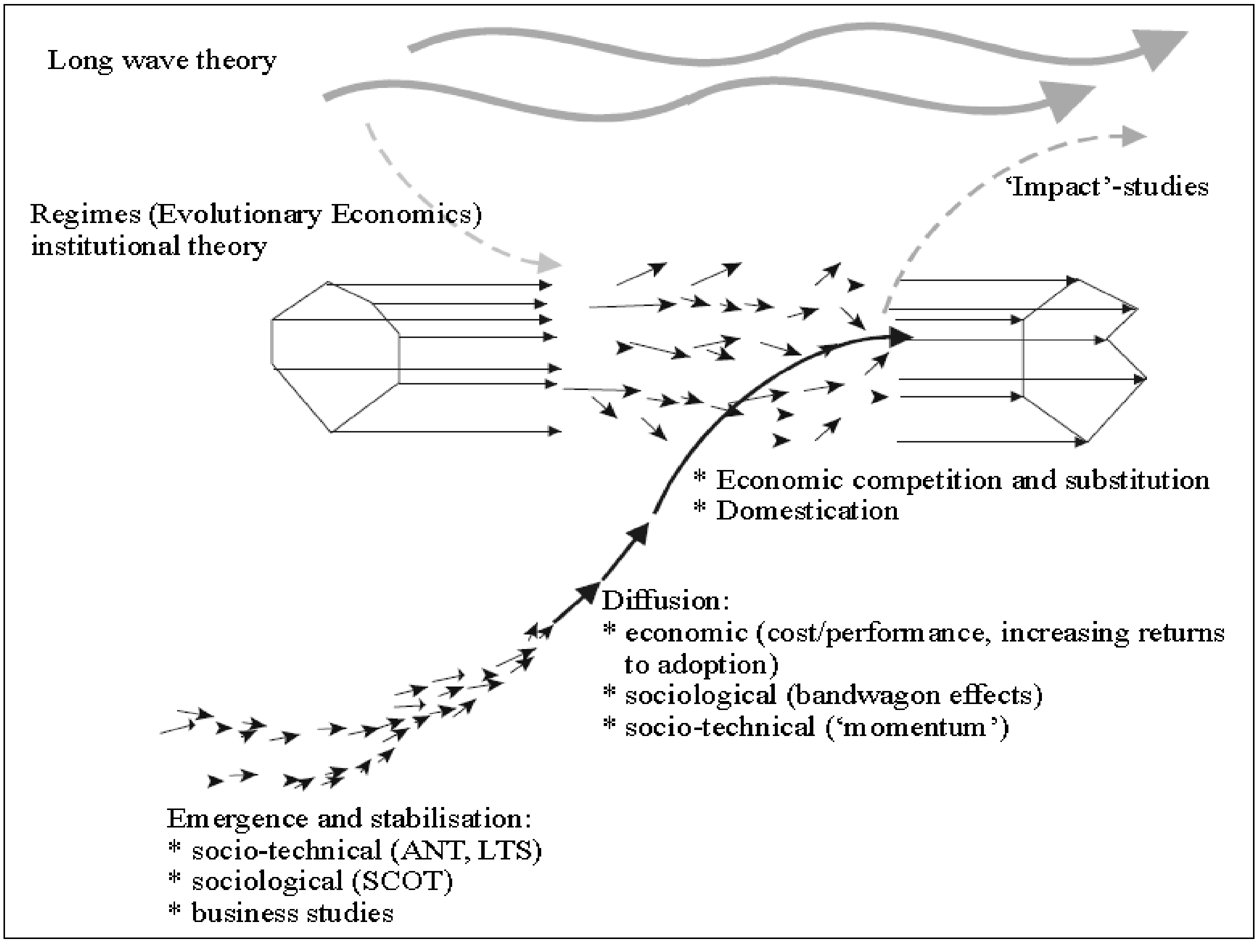


**Figure 2.7:** Positioning of different disciplines in the Multi level perspective (Source: Geels, 2006)

Geels (2006, pp 174-175) draws upon several mechanisms for diffusion of new technology so that the niche grows in size and stability niches i.e. internal drivers as in multi level perspective from different disciplines. These are discussed now.

**Economics:** Improvements in cost/performance ratios stimulate wider diffusion. The performance of the new technology may be improved as producers gain experience. There may be increasing returns to adoption as suggested by economic path dependent theorists.

**Sociology of technology:** In the sociological literature the focus is on actors, organizations, groups and their perceptions and strategic activities. It also highlights the importance of expectations and strategic visions of the future. Shared ideas about the future guide the direction of search activities. These visions can also be used by product champions as a strategic resource to attract attention and various kinds of protection mechanisms. All kinds of social mechanisms may accelerate or delay diffusion, *e.g.* hype and bandwagon effects, social struggles, effect of outsiders and strategic games.

**Social construction of technology, large technical systems and actor network theory:** In the social construction of technology approach (SCOT) the focus is on socio-cognitive processes which focus on discourses about technological artefacts (problem agendas, search heuristics, guiding principles) in the social groups that are involved in the development and use of those technological artefacts.In the socio-technical approaches of large technical systems (LTS) and actor-network theory (ANT) the focus is on linkages in and around the emerging technology. In both the perspectives new technologies emerge from processes of linking of heterogeneous elements through a process of creation of socio technical linkages and co evolution. Thus new technologies, markets, user preferences and regulations shape each other as a part of the translation and linkage process and lead to stabilization of rules at the niche level.

**Barriers to upscaling of niches**

Sustainable technologies face a large number of barriers due to several factors such as lack of user requirements in terms of performance and price, long lead development times, uncertainity about market demand and social gains and need for change at different levels in organization, technology, infrastructure and the wider social and institutional context. Furthermore existing regimes may be locked into existing technological competences and competencies, Strategic orientations may be locked in by structural relations to existing, cognitive routines may blind engineers,managers,politicians to developments outside their focus and create cognitive inertia and regulatory institutions may provide lock in to new developments (Geels et al, 2010; Kemp et al,1998).

According to Wustenhagen et al (2006) environmental externalities (the reduced environmental impact from use of renewable energy technologies does not necessarily lead to private benefits for customer. The discrepancy between private and public benefit is a serious barrier to both consumer and investor decisions for sustainable energy); capital intensity and long lead times (developing new energy technologies takes a lot of time and resources in research and development and setting up manufacturing facilities) and power of incumbents i.e. regime actors are some of the important barriers for successful commercialization of sustainable energy technologies.

Similarly according to Owen (2006) lack of scale economies and learning benefits; price distortions and imperfections in market with incumbent technologies; lack of information about renewable energy technologies; high transaction costs involved in renewable energy technologies; high consumer risk i.e. high pay back gap; difficulties in forecasting risks for consumers over a period of time; regulation based on traditional industry tradition and technology specific barriers may be some of the barriers associated with renewable energy technologies.

Teppo (2006); Tsoutsos et al (2005) also identify several barriers to development of niches and develop a typology of different barriers such as

Technological factors: Emerging renewable energy technologies are characterized by technological immaturity with respect to large scale deployment and optimization of user needs

Government policy or regulatory framework: Lack of stable policies and regulatory framework about new renewable energy technologies and their role in the energy system results in uncertainty about their future

Cultural and psychological factors: Due to lack of social acceptance is low emerging renewable energy technologies are not considered as a reliable alternative

Demand factors: Consumers and users cannot form specific expectations of the use and value of renewable energy technologies since users may be required to adjust their demands and preferences to new technologies and public benefits such as reduced environmental impact may not be turned into private benefits.

Production factors: Investment in new technology requires the sharp devaluation of existing facilities i.e. centralized mass production through coal, natural gas and oil to renewable energy sources which may make competencies in existing technologies obsolete.

Infrastructure and maintenance: The present network and infrastructure may not fit easily with renewable energy technologies.

Undesirable societal and environmental effects: Conflicts may also arise out of aesthetic or environmental concerns over the deployment of new installations of renewable energy technologies.

Economic factors: Due to sailing shift effect short term improvements in incumbent technologies may put off investments in emerging renewable energy technologies. High initial investments may also deter potential adopters in absence of financial mechanisms.

In the next section we discuss different dimensions in which niches can upscale.

**Dimensions of upscaling**

Based on the theoretical insights by Geels (2006) we develop three dimensions along which niches can upscale (economic, sociological and socio technical). Most analysis related to energy scenarios has paid insufficient attention to endogenous dynamics which relate to beliefs, struggles, interactions between various actors and social groups and instead paid attention to technological change conceptualized with learning curve and R&D investments. Hence there is a need for understanding changes in broad socio technical systems which not only include technology and markets but also infrastructure and markets, cultural aspects and consumer behavior (Verbong et al, 2010).Therefore we look at scaling from these three different perspectives.

**Table 2.2**: Different dimensions in which niches can upscale (Source: Own interpretation based on literature review)

| Dimensions for upscaling of niche | Empirical evidences |
|---|---|
| **Economic** | 1.Price/performance improvement<br>2.Increase in market share of niche technologies<br>3.Reduction in negative externalities<br>4.Reduction in capital intensity and lead time<br>5.Increase in number of adoptors/users over time |
| **Sociological** | 1.Hype and bandwagon effects, social struggles, media discourses, sustainability visions and scenarios<br>2. Widely shared and converging expectations; wide consensus, based on facts and experiences and tangible in nature |
| **Sociotechnical** | 1.Emergence of intermediary actors<br>2.Emergence of knowledge infrastructure through dedicated aggregation activities such as industry platforms, site visits, user organisations, sustained policy programmes, conferences, workshops<br>3.Standardization and institutionalization of cognitive rules in codes, standards, handbooks, textbooks such as developed by bureau of national standards<br>4.Structuration of formal and informal rules (preferences, heuristics, regulations, culture, norms) and increase in stability of rules<br>5.Anchorage (technological, network and institutional)<br>6.Niche regime interactions<br>7.Changing societal, cultural and cognitive beliefs and user preferences<br>8. Loss of legitimacy (regulatory, cognitive and normative) for regime |

Now we discuss the different dimensions of upscaling in detail

**1.Economic upscaling:** This involves price/performance improvement and cost reduction through upscaling scale and scope and learning curve effects. The performance of the new technology may be improved, as producers gain experience and by increasing returns to adoption. Sources of increasing return to adoption can include (1)learning by using: the more a technology is used, the more is learned about it, the more it is improved; (2)network externalities: the more a technology is used by other users, the larger the availability and variety of related products that become available and are adapted to the product use (3) scale economies in production, allowing the price per unit to go down (4) informational increasing returns: the more a technology is used, the more is known among users (5) technological interrelatedness: the more a technology is used, the more complementary technologies are developed. Further this can also involve increase in market share of the niche (Agnolucci et al, 2006; Geels, 2006; Geels et al, 2007; Sagar et al, 2006).

**Probable empirical evidences of economic upscaling**

1. Price/performance improvement: This can lead to higher performance in terms of more energy per watt from system (Geels, 2006; Geels et al, 2007; Grubler et al, 1999; Junginger et al, 2005; Kemp et al, 2009; Nemet, 2005; Pan et al, 2007; Sagar et al, 2006).

2.Increase in market share of niche technologies (Geels et al, 2007).

3.Reduction in negative externalities and internalization of costs for incumbent technologies (Wustenhagen et al, 2007; Zwaan et al, 2004).

4.Reduction in capital intensity and lead time for developing niche technologies (Teppo, 2006; Wustenhagen et al, 2008).

5. Increase in number of adoptors/users over time (Faber et al, 2009; Geels et al, 2007; Kemp et al, 2009; Rogers, 1996).

**2. Sociological upscaling**: This involves converging, shared and tangible expectations, beliefs, perceptions, practices and visions of niche actors (Geels, 2006; Geels, 2010; Konrad, 2006; Markard et al,2010; Raven et al, 2005;Schot et al,2007; Smith et al, 2010; Truffer et al,2008).

**Probable empirical evidences of sociological upscaling**

1. Hype and bandwagon effects, social struggles, media discourses, sustainability visions and scenarios and sailing ship effect (regime actors increasing their innovative efforts when challenged by niche actors): The ups and downs of enthusiastic expectations (real time representation of future technological situations and capabilities) can have a strong impact on innovation processes. An increasing number and variety of actors may be attracted and further resources mobilized for the development of the innovation. Actors strategically inflate and communicate technological promises in order to attract attention and resources. When visions and expectations are accepted, action needs to be taken in order to realize them. In some periods of time the process of raising, accepting and acting upon expectations leads to commitment to overly optimistic expectations. When these expectations cannot be met it may lead to disillusionment and protective spaces may be cancelled if the overpromising expectations are not met. However If the hyped expectations are widely shared they act as a coordinating device for the innovation activities of heterogeneous actors (Geels, 2006; Markard et al, 2010; Mc Dowall et al, 2006).

2. Dynamics of expectations (widely shared and converging expectations; wide consensus, based on facts and tangible in nature): External circumstances or developments in existing niches (e.g. breakthrough in R&D research) may create new opportunities for a technology. Actors raise high expectations about the technology. Expectations can be of different kinds i.e. specific expectations about specifications of artifacts, systems, processes, products or specific projects; generalized expectations about the future of the technological field and socio technical visions in form of scenarios about the technology as a whole, about social, political and economic aspects about new technological trends.

Collective expectations play an important role in motivating large number of actors even if they may hold a priori marginal interest in the innovation field. Actors are willing to protect a non profitable innovation for realizing shared and collective visions often based on the beliefs that innovation will be viable in the future through technical improvements or anticipated changing selection pressures. Expectations raised by industry analysts and promissory organizations producing future oriented knowledge claims: Industry analysts may articulate both generic visions of a technical field. Such organizations also produce future oriented knowledge claims and shape the development of the technology. The analysts also specialize in production, commodification and selling of future oriented knowledge to exert influences on shaping of technology Shared visions and expectations of the future can be powerful forces in the shaping of technology, directing and constraining research efforts by providing a mental map of future and creation of protective mechanisms even if the performance of the new technology is poor (Berkhout, 2006; Buchholz et al, 2009; Geels, 2006; Konrad, 2006; Markard et al,2010; Pollock et al, 2010; Raven, 2005; Rohracher, 2003; Schot et al, 2007; Smith et al, 2010; Sovacool et al,2010; Spath,2010; Truffer et al,2008; Van lente et al,2008).

**3.Sociotechnical upscaling**: This involves structuration of formal and informal rules (Preferences, heuristics, regulations, culture, norms) and stability (technology, user practices, infrastructure, networks).This also involves anchorage (technological, network and institutional) (Berkhout et al, 2010; Elzen et al, 2008; Geels, 2006 ; Geels et al, 2006; Raven, 2005; Raven et al, 2009; Rotmans et al, 2008; Smith,2007).

**Probable empirical evidences for sociotechnical upscaling**

1.Emergence of intermediate actors such as standardization organizations, professional societies, industry association etc (Deuten, 2003; Geels et al, 2006; Raven et al, 2009; Raven et al, 2010).

2.Emergence of knowledge infrastructure through dedicated aggregation activities such as conferences, seminars, workshops, courses, technical journals, proceedings etc (Deuten, 2003; Geels et al, 2006; Raven et al, 2009; Raven et al, 2010).

3.Division of cognitive labour in form of local (practical, technical work in local practices) and global knowledge activities (standardization and institutionalization of cognitive rules in codes, standards, handbooks, textbooks etc) (Geels, 2010).

4.Structuration of formal and informal rules (preferences, heuristics, regulations, culture, norms) and increase in stability of rules for the emerging niche (Raven, 2005).

5.Anchorage (technological, network and institutional) (Berkhout et al, 2010; Elzen et al, 2008).

Technological anchorage

Novel technical artefacts, concepts and practices in relation to the technology that are worked on in niches become more defined (Elzen et al, 2008, Berkhout, 2010).

Network anchorage

Heterogeneity of actors (Actors from the technical and social world such as industry, research, organizations, users, policy makers, NGO's) (Raven, 2005).

Presence of regime outsiders(actors such as innovative, new firms, academic professionals or societal pressure groups who do not represent the prevailing regime and hence have no vested interests)(Van de Poel,2000)

Increased involvement, intensified contact and exchange of regime and hybrid actors in niche activities (Elzen et al, 2008; Geels et al, 2010).

Institutional anchorage

Changes in interpretive, normative, economic rules (Berkhout et al, 2010).

6. Niche regime interactions (Raven, 2005).

7.Changing societal, cultural and cognitive beliefs and user preferences: Wide adoption of new technologies requires efforts by users to domesticate and integrate new technologies into their user practices, integrating them into their daily lives and making sense of them. This may involve symbolic work, practical work and cognitive work by the users (Geels, 2004; Geels, 2006; Geels et al, 2010; Rohracher, 2003).

8. Loss of legitimacy (regulatory, cognitive and normative) for regime (Geels, 2010; Geels et al, 2010).

**Measurement of evidences for upscaling of niches**

Although we have presented a list of probable evidences which can be used to discuss up scaling of niche there are lot of methodological challenges (qualitative as well as quantitative) in empirically assessing up scaling in different dimensions (economic, sociological and sociotechnical).Furthermore upscaling in one dimension may be dependent on the other i.e. for example improvement in price/ performance may be dependent on other factors such as collective expectations among actors or supportive institutions. This makes it quite challenging to study upscaling.

**Economic upscaling**: Insights from environmental evolutionary economics by Faber et al (2009) ; Kemp et al (2009) can be used to develop models for economic scaling apart from the literature discussed before. However this will also involve development of complex mathematical models based on a large number of assumptions and biases which in the end may not be highly accurate.

**Sociological upscaling**: Insights from sustainability foresight approach and workshops which aim at constructing plausible transformation scenarios for sectors and deducing embedded innovation strategies in a multi-stakeholder setting can be used for understanding dynamics of expectations and a basis for alignment of strategies in course of shaping sustainable transformation processes (Truffer et al, 2008). Other techniques such as participatory multi criteria analysis in the context of renewable energy technologies can be also be used to develop scenarios and visions in decision making about long term consequences by projecting different pathways in future.

Exercises such as forecasts (quantitative extrapolation and modeling to predict likely future);exploratory scenarios(exploration of possible futures with no predetermined desirable end state); technical scenarios(scenarios specifying technical feasibility and implications of different options);visions(elaborations of a desirable and a more or less plausible future); backcasts and pathways( starting with a predetermined pathway and desirable future and investigating possible pathways to the point) and roadmaps(a sequence of measures designed to bring about a desirable future) can also be used for mapping such expectations (Mc Dowell et al, 2006).

Qualitative and quantitative analysis of media attention expressed in newspaper articles, news etc can be also used for mapping expectations (Kowalski et al, 2009; Markard et al, 2010; Mc Dowall et al, 2007).These techniques can be used for understanding dynamics of expectations and sociological scaling in general. However these techniques are also subjected to problems due to lack of transparent expectations during workshops. Different actors may manipulate and play games even during the workshops leading to several methodological challenges.

**Sociotechnical upscaling**: Based on research by Frank W Geels [12] case studies can be used for understanding socio technical scaling. Insights from process theory which focuses on events and actors who react to each other and make decisions, based on beliefs and interests that change over time can offer interesting insights into understanding sociotechnical scaling. However historical case studies also suffer from analyst bias in terms of selection of cases and data and flawed use of secondary and primary data sources. Thus there are a lot of methodological challenges in measuring sociotechnical scaling as well.

**Mechanisms for upscaling of niches**

Now we discuss different mechanisms through which up scaling may take place.

1.Pressure from landscape: The Multi Level Perspective argues that transitions come about through interactions between processes at these three levels: niche innovations building up momentum, changes at landscape pressure creating pressure on regime and destabilization of regime and instability in regime creating opportunities for niche. However it is important that landscape pressure should occur on regime at a time when niches have become highly stable. If landscape pressure occurs at a time when niche-innovations are not yet fully developed; the transition path will be different than when they are fully developed (Geels, 2002; Geels, 2004; Geels et al, 2007; Raven, 2005).

2.Pressure on regime through internal problems in regime (triggering events, questioning of regime, decreasing commitment and loss in faith in terms of meeting societal needs , protests by activists and social movements, changes in societal beliefs and discourses, changing government regulations and institutional pressures, mismatch with institutional environment ) ; increasing strength of pressure through stricter regulations (financial and regulatory instruments like carbon tax, emission trading schemes, emission norms, performance standards) in reaction to negative externalities (Geels, 2006;Geels et al,2010;Verbong et al, 2010).

In this respect it is also important that a certain degree of regime stability seems to be needed for successful niche breakthrough. Certain degree of instability in the regime increases chances for breakthrough of niche but again start to decrease with further increasing instability. This is also shown in the figure below.

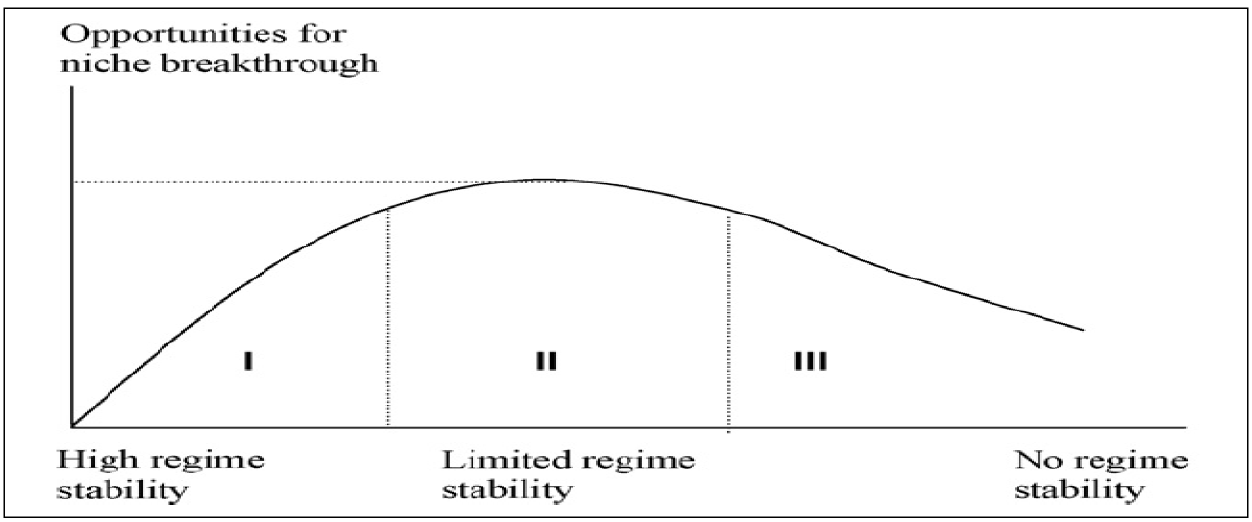


**Figure 2.8:** Relationship between niche breakthrough and regime stability (Source: Raven, 2005)

[12] http://www.sussex.ac.uk/profiles/228052

This is particularly important in context of developing nations as discussed since too much instability in the regime can also reduce chances of niche breakthrough even if niche innovations are fully developed.

3. Development of niches: Development of niches should take place through four processes i.e.

1.Dynamics of expectations
2.Network management
3.Learning mechanisms
4.Gaining legitimacy

We add another important process i.e. gaining legitimacy apart from the three main processes discussed before.

**Dynamics of expectations:** To understand how upscaling of niches take can place we need to first understand how collective expectations are formed which lead to development of protective spaces where niches can develop. However the mechanisms of securing and withdrawing protection for niches is quite complex and to a large extent will depend on the collective expectations of actors and politics, power and interests of different actors. Reduced collective expectations, negative feedback and experiences, disappointments may lead to unraveling of protective spaces thus hindering development of niches. The mechanism through which expectations lead to development of protective spaces is shown below.

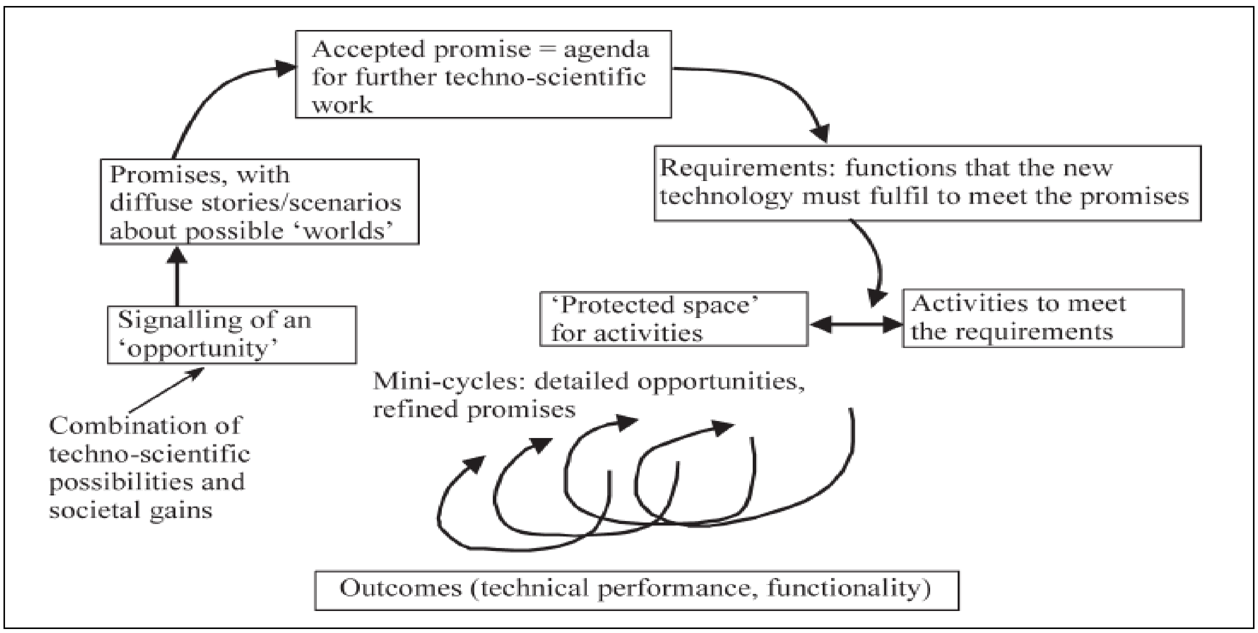


**Figure 2.9**: Promise requirement cycle in technological development (Source: Geels, 2007)

Collective expectations may also lead to large number of actors who may not be interested in the innovation field but may be ready to protect the innovation for realized shared and collective visions and specific benefits in future. Expectations can become more robust, quality of expectations can rise and become more specific over a period of time (Geels, 2007; Konrad, 2006; Raven, 2005; Spath et al, 2010).

**Network management:** The focus should be on bringing heterogeneous actors (Actors from technical and social world such as industry, research, organizations, users, policy makers, NGO's); regime outsiders (innovative firms, academic professionals, societal pressure groups with no vested interests in regime) and increased involvement of regime and hybrid actors (Elzen et al, 2008; Geels et al, 2010; Raven, 2005; Van de Poel, 2000).

**Learning mechanisms:** There is a need for learning mechanisms in terms of (design specifications, required complementary technology and infrastructure; user characteristics ,meanings and requirements they attach to the technology and barriers encountered; long term societal and environmental impact of technology and industrial development i.e. production and maintenance network needed to broaden the dissemination process. Learning should also focus on co evolution and alignment between technical (e.g. technical design, infrastructure) and the social (e.g. user preferences, regulation and cultural meaning) rules for the niche. Learning should also focus on questioning and destabilization of existing beliefs and routine (early questioning, increasing doubt, loss of faith and switching to new beliefs and routines) through double loop learning (Geels et al, 2010; Raven, 2005; Raven et al, 2009; Raven et al, 2010).

**Gaining legitimacy:** In the sector the incumbent technologies, actors and institutions are very powerful and highly organized as they had decades to secure their positions as familiar and socially accepted. Incumbents are not only hesitant towards adopting new technologies but may also deliberately attempt to block the development of new emerging technologies. Niche actors may need to gain legitimacy (institutional alignment in cognitive, normative and regulative dimensions). It is necessary to attain legitimacy in order for resources to be mobilised, for demand to form and for actors in to acquire political strength. Concerted actions through advocacy coalitions, rise and growth of interest groups, lobbying activities, political debates in parliament and media can help the niche actors in gaining legitimacy. (Bergek et al, 2008; Bergek et al, 2008; Geels,2010; Hekkert et al, 2007).

4.Suitable protection mechanisms: The incumbent regimes constitute an unfavorable selection environment for emerging niches. Niches need protective spaces where they can develop and can scale up.The temporary development and gradual withdrawal of a protective space around niche experimentation is central to the theory. There can be several forms of protection mechanisms such as economic, institutional, socio cognitive, cultural, geographical, and political. This is mentioned in the table below.

**Table 2.3**: Different forms of protection mechanisms: (Source: Raven et al, 2010)

| Form of protection | Empirical indicators |
|---|---|
| *Economic* | Public grants; price support; purchase obligations; RD&D funding; feed-in systems; long-term private investment commitments; |
| *Institutional* | Planning rules; grid connection rules; insurance schemes; rule exemptions (e.g. for environmental reporting); development of supporting norms and standards |
| *Socio-cognitive* | Promising claims; feasibility studies; training schemes; research programmes; conferences; best practice publications; establishment of intermediary organisations; |
| *Cultural* | References to the technology in wider symbolic context; statements of what the technology signifies for prevailing social values (of group or society); art such as images, movies and stories that positively portrait the technology; |
| *Geographic* | Locations of experiments with respect to resource endowments; proximity to existing infrastructures; articulated fit with local (socio-economic) problem agendas; |
| *Political* | Statements that link technologies to political goals; explicit mentioning of technologies in white papers; Ministerial commitments. |

The table below presents a detailed overview of protection mechanisms which can be used for development of niches

**Table 2.4:** Overview of different protection mechanisms for upscaling of niches (Source: Based on own interpretation, literature review and information from MNRE website[13])

| **Form of protection** | **Protection mechanisms** |
|---|---|
| Economic | Fiscal incentives; direct and indirect tax benefits; long term financing mechanism; tax holidays; duty exemptions; reduction in excise and VAT tax; subsidized interests rates and soft loans; import and export subsidies; R&D funding; renewable power purchase obligations; renewable energy certificates; feed in tariffs; subsidies for manufacturing; specialized incentive instruments(renewable energy vouchers, capital subsidy, interest subsidy, viability funding, green energy bond), appropriate consumer financing mechanisms etc |
| Institutional | Modifications in electricity act and laws; changes in banking regulations for consumer financing (mainstream banking ,micro finance and rural banking institutions); modifications in existing regulations(Land acquisition and leasing,water,pollution); setting up of autonomous authority, mission steering groups(representatives from different ministries) for renewable energy; modifications in regulations at national,regional,state,district,local level etc |
| Socio cognitive | Renewable energy surveys, assessment and mapping; reliability and performance evaluation studies for new solutions; enhancing domestic manufacturing base, development of testing facilities for emerging technologies and standards(eg Bureau of Indian standards), international level quality accreditation mechanisms; technology transfer mechanism; development of IPR mechanisms; investments in human capital(training of scientists and engineers, short term and long term courses, fellowships, training programmes in sales and services, entrepreneurial development centers, new university research centers); research programmes and co operation between industry and academia; development of intermediate associations; multi stakeholder conferences on best practices; forums for knowledge sharing etc |
| Cultural | Outreach and training programmes for greater public awareness; specialized incentives to grass root movements and NGO’s for awareness campaigns; knowledge portals for common public; setting up of more public think tanks, citizen forums and activists group for educating people; supportive media(News, print, electronic) |
| Geographic | Development of green clusters, regional innovation systems, special economic and manufacturing zones(e g specialized location for semiconductor manufacturing); development of certain regions for development of renewable energy such as solar parks, solar cities; supportive infrastructure(Land, water, electricity and other resources) to certain geographies where there is a potential for development of renewable energy |
| Political | Ministerial commitments for energy and environmental security; statements and commitments in international climate change and energy forums; statements aiming at becoming global leader in renewable energy; political support for job creation potential(R&D,manufacturing, installation, maintenance) ; mission and vision documents etc |

[13] http://www.mnre.gov.in/

However continuous protection can become wasteful when it becomes clear that the prospects for the niche are not good enough or in the opposite case as well when niches have developed to such a extent that it can be exposed to market pressures. However in reality it is very difficult to assess when to increase and decrease the protection (Berkhout et al, 2010; Kemp et al, 1998; Romijn et al, 2008; Schot et al, 2008; Smith et al, 2009; Ulmanen et al, 2009).

While protection of niches should be increased and gradually decreased when niches become stable , the protection of regimes should also be decreased through several mechanism such as (taxes, reduction in government support, regulatory pressure, decrease in legitimacy, reduction in political support, shift in policy discourses, etc) (Geels et al,2010).

5. Stable political environment, regulatory support and good governance mechanisms: Transitions theory tends to underplay specific conditions such as actor constellations, political strategizing, discursive orientations, institutional structures, and the political histories that produced them. Economic actors associated with established technologies are not enthusiastic about alternatives that would render their competencies obsolete. Thus long term changes will be messy due to political dimensions of transitions, and committing public resources to support technological change involves controversial political choices.

Sustainable transition pathways must operate across all multiple policy domains and bring together political jurisdictions at multiple levels. Horizontal divisions within government has also made the situation more complex with various regulatory, administrative functions. This has lead to split of political power among various actors such as political leaders, party activists and the electorate. This is also coupled with timeframes of electoral cycles, normative discourses around sustainability pathways confronting political interests and struggle for accommodation within existing institutions. To uncover these issues there is a need for understanding how power permeates and becomes embedded in socio technical systems, how actors come to exercise countervailing power over the systems and how does the distribution of power affects capacities for system innovation. A transition towards truly sustainable societies is inevitably a deeply political process with winners and losers. Hence understanding the politics of transitions and the role and dynamics of both resistance and advocates embodied in social movements is a critical challenge .For successful transitions a stable political environment, regulatory support and good governance mechanisms (public participation, transparency, accountability and capacity and the extent to which they are practiced, protection of consumer interests and corruption free environment) are extremely necessary (Dixit, 2007; Grin et al, 2007; Grin et al, 2009 ; Meadowcroft, 2007; Meadowcroft, 2009; Parthan et al,2010; Raven et al, 2010; Smith et al, 2009; World Bank Group, 2006).

6.Transnational linkages: Upscaling is likely to involve knowledge and capability building and development of niches and experiments through global networks and linkages such as international financing institutions and foreign direct investments, transnational links through direct or indirect relationships with foreign technical experts, multinational technology suppliers, maintenance firms, joint ventures and licensing agreements, overseas development assistance and regional, national and international policy actors (Berkhout et al, 2010; Raven et al, 2010; Verbong et al, 2010).

Apart from these mechanisms performance of new technology as mentioned before can be improved by learning by using, network externalities, and allowing economies of scale, informational increasing returns and development of complementary technologies. There are also endogenous mechanisms (awareness of existence of an innovation, learning economies, effect of complimentary innovations and increased competition from other technologies) and exogenous mechanism (Changes in energy prices, regulations and market and industry structure) which can be responsible for improvements in performance of technology (Baretto et al,2008; Geels,2006; Kemp et al,2008).

A combination of these mechanisms may lead to up scaling or growth of the niche which can transform the existing regimes through one or a combination of different transition pathways. Since transitions are multi faceted process it is difficult to point out exact factors in terms of dependent and independent variables which can discuss up scaling. The mechanisms discussed can be some of the several mechanisms for up scaling. In the next section we dicuss up scaling of experiments.

## 2.11 Upscaling of experiments

Since experiments in our research are social enterprises and their activities we focus on up scaling of social enterprises. According to Smith et al (2009) social entrepreneurs often consider how to grow or expand the social value of the organization. In the context of social entrepreneurship scaling can be defined as increasing the impact a social-purpose organization produces to better match the magnitude of the social need or problem it seeks to address' While management and entrepreneurship scholars have focused substantial attention on the growth and scaling of commercial ventures, relatively less attention has been paid to the unique issues associated with scaling entrepreneurial solutions to public problems. The figure below presents the theoretical framework which is used to discuss up scaling of experiments.

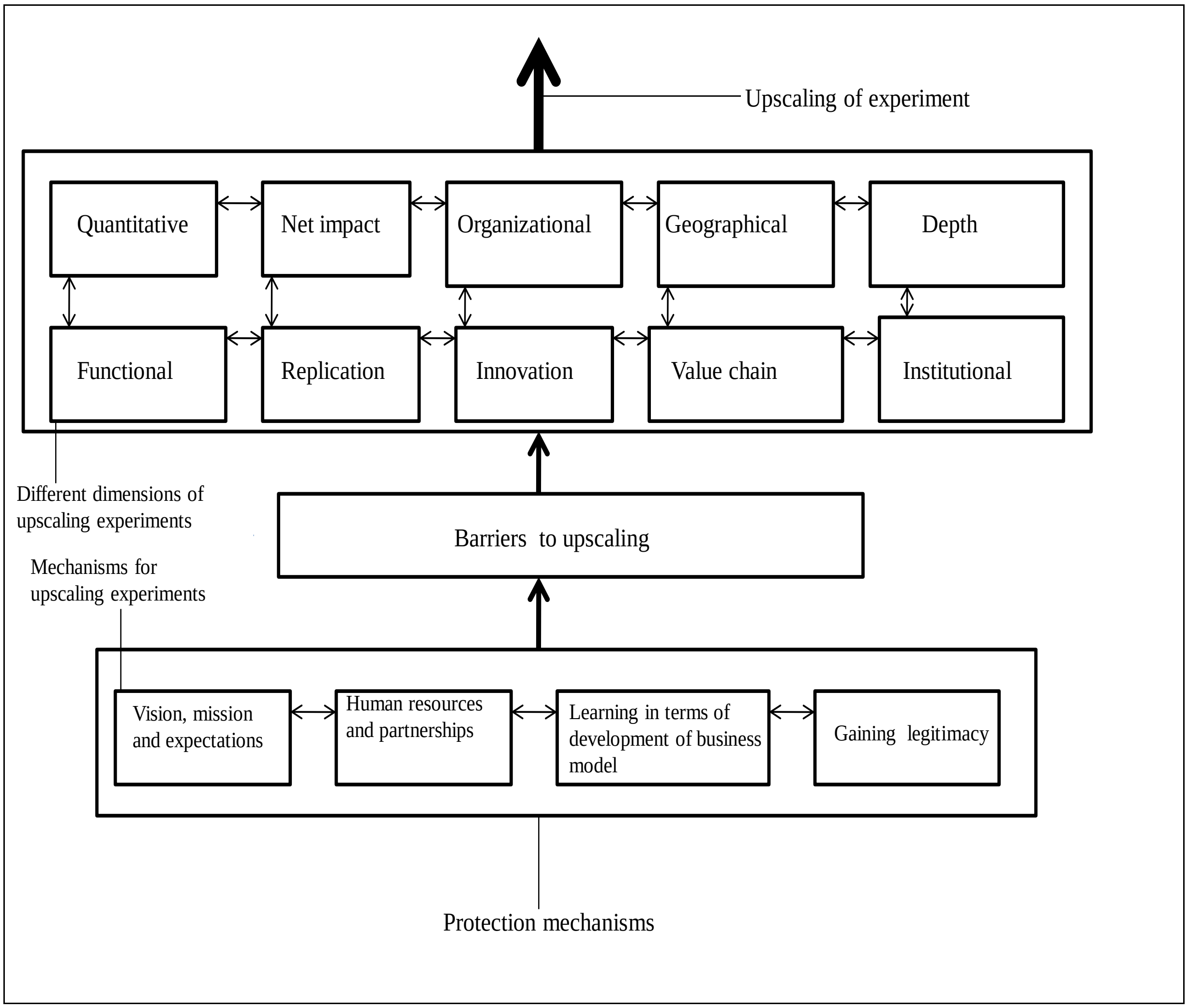


**Figure 2.10**: Upscaling of experiments (Source: Own interpretation based on literature review)

Now we discuss the theoretical framework. i.e. different dimensions of upscaling experiments. These dimensions have been identified on basis of literature review on scaling of social enterprises, bottom of pyramid as mentioned before. Substantial amount of literature already exists on upscaling however we identified only these dimensions which we feel are relevant for the research. The dimensions are

1.Quantitative: Scaling in terms of number of beneficiaries (Rogers et al, 2006).

2. Net impact: Scaling in terms of more value created for beneficiaries, society and the world [14](Lall, 2010; Mair et al, 2006; Nicholls, 2009; Westall, 2007; Yunus et al, 2010; Zahra et al, 2009).

3.Organizational: Scaling in terms of expanding the capacity of existing business i.e. (developing resources, building a knowledge base, employing people, management systems) (Klein, 2008; Westall, 2007).

4. Geographical: Scaling in terms of geographical expansion i.e. (serving more people in new regions and extending into new markets) (Dees, 2008; Klein, 2008; Karmachandani et al, 2009).

5. Depth : Scaling in the sense of deep scaling (Reaching increasingly poorer segments of population) (Rogers et al, 2006; Smith et al, 2009).

6.Functional : Scaling in terms of developing new products and services (CGIAR NGO, 2000; Klein, 2008; Karmachandani et al, 2009).

7.Replication: Scaling in terms of replication, supporting and incubating new entrepreneurs [15](CASE, 2008; Westall, 2007).

8.Innovation: Scaling in terms of increasing research and development, innovation, ideas and knowledge (CASE, 2008; Westall, 2007).

9.Value chain: Scaling in terms of deepening and upgrading in the external value chain (CASE, 2008; Westall, 2007).

10. Institutional: Scaling in terms of transforming existing institutions and creating new ones (Macguire et al, 2004; Mair et al, 2006; Robbin, 1984; Sud et al, 2008).

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[14] http://blog.acumenfund.org/author/khill/
[15] http://www.thinkchangeindia.org/2009/09/09/tc-i-changemakers-a-conversation-with-dr-harish-hande-of-selco/

The dimensions along with empirical indicators are presented in the table on the next page.

**Table 2.5**: Different dimensions on which experiments can upscale (Source: Own interpretation based on literature review)

| **Dimensions for upscaling of experiments** | **Empirical indicators** |
|---|---|
| Quantitative | Number of beneficiaries/people |
| Net impact | Improved standard of living and livelihood, improved education, cost savings, income generation, reduced fuel usage and smoke due to usage of fossil fuels, reduced green house gas emissions, improved health conditions and reduction in diseases |
| Organizational | Improvement in technical and managerial capacity, organizational growth, improving internal management and staff capacity, development of infrastructure and resources, development of knowledge base and management systems, diversifying funding sources and becoming financially self sustainable |
| Geographical | Expansion to new geographical locations (local communities ,village, municipalities , regions, states, nations) |
| Depth | Reaching extremely poor and vulnerable section of the population |
| Functional | Expansion in number and type of activities, new products and services |
| Replication | Number of new entrepreneurs created, affiliates, increase in multi site organization i.e. branching, franchising |
| Innovation | Dissemination of knowledge and ideas, research and development activities, knowldege development through patents and investments in R&D,social innovations |
| Industry specific | Movement up the technology (PV) value chain i.e. from balance of systems to metallurgical silicon production |
| Institutional | Modification in public policy at national and international level, transformation of existing institutions ( regulative, normative and cognitive) |

## Measurement of indicators for upscaling of experiments

In contrast with measurement measurement of indicators for up scaling of niche there are less methodological challenges in measurement of indicators for up scaling except for few dimensions such as net impact, innovation and institutional scaling.[16] Some ways of measuring them can be impact surveys conducted by different organizations. However there are still challenges since many enterprises may not document or collect data over a period of time making it difficult for analysts and researchers to understand up scaling.

### Mechanisms for upscaling experiments

This section describes the mechanism for up scaling of experiments. These mechanism have been derived from the niche processes as in SNM (dynamics of expectations, social networks and learning mechanisms).However we also add important factor i.e. gaining legitimacy since niche actors also need to engage in cultural framing actions to enhance the legitimacy of niche innovations, which initially suffer from the liability of newness and are perceived as strange, inappropriate or out of place (Bergek, 2008; Geels, 2010; Geels, 2010).

1. Developing vision, mission, ambition and expectations

2. Learning in terms of development, financing and implementation of business model

3. Developing human resources and development of social networks, partnerships

4. Gaining legitimacy

The mechanisms for up scaling of experiments are explained now.

## 2.11.1 Developing vision, mission and expectations

Expectations help to guide activities, provide structure, attract interests and give definition to roles, offer a shared vision and open up potential for present day promises to be held to future account (Borup et al, 2006). Individually formed expectations held by entrepreneurs may be decisive for innovation success more than expectations held by other actors in the society (Truffer et al, 2008).There may be variations in how enterprises can scale. Such variations  arise a result of their motivations and preferences, nature and difference in goals, motivations, strategic intent pursued by different social entrepreneurs which is also to a large extent dependent on ambition of entrepreneur (Klein ,2008; Zahra et al, 2008.)

Vision guides the entrepreneur's long journey towards establishing new ventures. For entrepreneurs visioning is about seeing their business in the future and an ideal to which the organization should aspire, or a mental image of products and services the entrepreneur wants to achieve. Vision is central to the entrepreneurial process and also accounts for the venture's performance and growth. In social enterprises vision is highly important since it guides the entrepreneur to ideologies, values and mission. Most social entrepreneurs try to communicate their vision to as many individuals as possible and success is also directly connected to number of people influenced by their vision (Brush et al, 2008; Raynor, 1998; Ruvio et al, 2010).

[16] Measurement of these indicators requires detailed  research with focus on  ( day to day activities) with well developed methodologies over a period of time  with close co operation with the enterprise which often is difficult

### 2.11.2 Learning in terms of development, implementation and financing of the business model

Social enterprises need to make learning an important part of their process. Learning should aim at double loop learning i.e. questioning the governing variables, values and assumptions after single loop learning i.e. given or chosen goals, values and plans are operationalized rather than questioned. It is also important to know that double loop learning occurs when error is detected and corrected in ways that involves modification of an organization norms, policies and objectives[17] (Argyris et al, 1978). Enterprises then should try to reconcile new perspectives and knowledge with their existing perceptive through double loop learning (Klein, 2008).

According to Osterwalder et al (2005) a business model is a conceptual tool that contains a set of elements and their relationships and allows expressing the business logic of a specific firm. It is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing and delivering value and relationship capital to generate profit and sustainable revenue streams. The business model as a system shows how the pieces of a business concept fit together while strategy also includes competition and implementation. Business models change may rapidly with time and keep on evolving from present state to desired state or new business model.

The concept of business model has been derived from various theories of the firm namely transaction cost economics, resource based view, relational view, dynamic capabilities, absorptive capacity, complementary and strategic assets, appropriability regime and value chain analysis (Rasmussen, 2007).

The various components of a business model are shown in the figure below

**Table 2.6 :** Various components of a business model (Source: Osterwalder et al, 2005)

| Pillar | Business Model Building Block | Description |
|---|---|---|
| Product | Value Proposition | Gives an overall view of a company's bundle of products and services. |
| Customer Interface | Target Customer | Describes the segments of customers a company wants to offer value to. |
| | Distribution Channel | Describes the various means of the company to get in touch with its customers. |
| | Relationship | Explains the kind of links a company establishes between itself and its different customer segments. |
| Infrastructure Management | Value Configuration | Describes the arrangement of activities and resources. |
| | Core Competency | Outlines the competencies necessary to execute the company's business model. |
| | Partner Network | Portrays the network of cooperative agreements with other companies necessary to efficiently offer and commercialize value. |
| Financial Aspects | Cost Structure | Sums up the monetary consequences of the means employed in the business model. |
| | Revenue Model | Describes the way a company makes money through a variety of revenue flows. |

[17] http://www.infed.org/thinkers/argyris.htm

The customer interface with reference to Table 2.5 constitutes an important part of business model and it is crucial for a firm to be aware of the potential target customers in order to formulate in a coherent and correct value proposition. Partners are external actors involved directly or indirectly involved in value generation of a particular business. The value configuration denotes which parts of the value chain are performed by the enterprise and whether it specializes in certain value steps or integrates larger parts of the value chain. The cost structure and revenue model describes how value delivered to the market is translated into sales, revenues and profits. It focuses on economic bottom line of the business (Wustenhagen et al, 2007).

Core competency is about collective learning in the organization as to how to co ordinate diverse production skills, integrate multiple stream of technologies, organization of the work and delivery of the value. Core competency does not get diminish with use; competencies are enhanced as they are applied and shared and competencies need to be nurtured and protected (Prahalad et al, 1990). Core competency can be applied by three tests i.e. whether it is a significant source of competitive differentiation, whether it transcends to single and range of businesses both new and current and whether it is hard for competitors to imitate (Prahalad, 1993).

According to Seelos et al (2010); Yunus et al (2010) social business models involve challenging the conventional wisdom, setting up partnerships, undertaking learning and experimentation, finding socially oriented stakeholders and encouraging double loop learning in contrast to single loop learning which is confined to changing strategies within an existing framework. The various components of a social business model in terms of the value proposition are i.e. how the enterprise offers value to the customers; value constellation i.e. partners of the enterprise and value network; and a profit equation i.e. how value is captured from the revenues generated through value proposition and how costs are structured and capital is employed in value constellation. The profits earned are reinvested back into the business unlike a conventional business in which profits for shareholders are maximized.

According to Freund (2009); Stubbs et al (2008) business model for sustainability is the activity system of a firm which allocates resources and coordinates activities in a value creation process which overcomes the public/private benefit discrepancy. Sustainable business models can be developed by extending value proposition to integrate both private as well as public benefits i.e. positive effects like reduced social and environmental impact due to business activities. Since we are focusing on social enterprises which are focusing on provision of sustainable energy solutions for the poor we try to develop the components by integrating insights from literature of conventional, social and sustainable business models. Based on Freund (2009); Klein( 2008); Osterwalder (2005); Stubbs (2008); Wustenhagen (2007); Yunus (2005) we try to develop conceptual model for the development of business model t which is relevant for studying upscaling of experiments as done in this thesis. The various components of the business model are discussed below.

**Products and services:** This comprises not only the company's bundles of products and services but the manner in which it differentiates itself from its competitors. Sustainable and social business models need to be developed in such a way that customers are willing and able to pay higher for positive ecological attributes and public benefits such as sustainability. Reduced emissions turn into private benefit in form of the value proposition. Social enterprises serving people at the Bottom of Pyramid also need to provide value proposition in terms of fulfilling needs of the poor people, reinventing cost structures according to paying capacities of poor, increasing consumer accessibility and affordability, increasing usability in hostile environments (noise dust, unsanitary conditions, electrical black outs), increasing social comfort (while taking heterogeneous consumer base, language and socio economic diversity into account), consumer education and access to information, generate productive employment of assets and dead capital as well as build gaps in local infrastructure. Enterprises also need to co create to achieve joint value creation by allowing the customer to co construct the service and product and experience to suit his/her context and creating an experience in which consumers can have active dialogue and co-construction of personal experiences (Freund, 2009; Klein, 2008; London et al, 2009; Prahalad, 2004; Sheombhar, 2009; Vermeulen, 2009).

**Customer interface:** Customer interface describes how and to whom the enterprise delivers its value proposition, which is the firm's bundle of products and services. This comprises the choice of the enterprise's target customers, the channels through which it gets in touch with them and the kind of relationships the company wants to establish with its customers. However the enterprise needs to maximize customer value by means of market segmentation, supply chain design and relationship building to bridge the public/private gap. For people at the Bottom of Pyramid customer interface needs to be designed in such a way that there is engagement with the local community as well as increase in trust with the local community. Enterprises also need to focus on co development of solution through active and participatory engagement with local people (Freund, 2009; Klein, 2008).

**Infrastructure management:** Infrastructure management describes the value system configuration that is necessary to deliver the value proposition and maintain customer interfaces. It also comprises the value configuration of the firm, the in house capabilities and those acquired through the firm's partnership network. Infrastructure management of a business model for sustainability should take advantage of partnerships to enhance resources and activities in a way that promote sustainable development. Social enterprises need to focus on localization of value creation, developing a model indigenous to local culture, norms, traditions and institutions (Freund, 2009; Klein, 2008).

**Financial aspects:** Financial aspects describe the enterprise's revenue model and cost structure. Together they determine the firm's profit or loss making logic and therefore its ability to survive in competition. The revenue model consists of different streams and pricing mechanisms. The simple equation: Revenue - costs = profit/loss for conventional businesses needs to be modified to include environmental and social profits and losses which are also not always to calculate. The enterprise needs to develop socially profit oriented stakeholders, reduce the environmental impact of its operations and become economically viable for recovery of cost and capital employed. Enterprises also need to make sure that profits are not achieved at the cost of compromising environmental and social value (Freund, 2009; Yunus, 2010).

Enterprises also need to deal with organizational inertia resulting from previous business model design. They may need to renew their existing business models to avoid lock in effects. They need to continuously experiment through trial and error based learning .However there is still a gap between business model conceptualization and final implementation on the ground which needs, more understanding and research (Sosna et al, 2010).

Till now we have discussed the design of business model but the business model needs to be financed and implemented through a trial and error learning process. Business model implementation and management includes translation of the business model into a business plan and more concrete elements such as business structure i.e. departments, units, human resources, infrastructure and system. This is shown in the figure below.

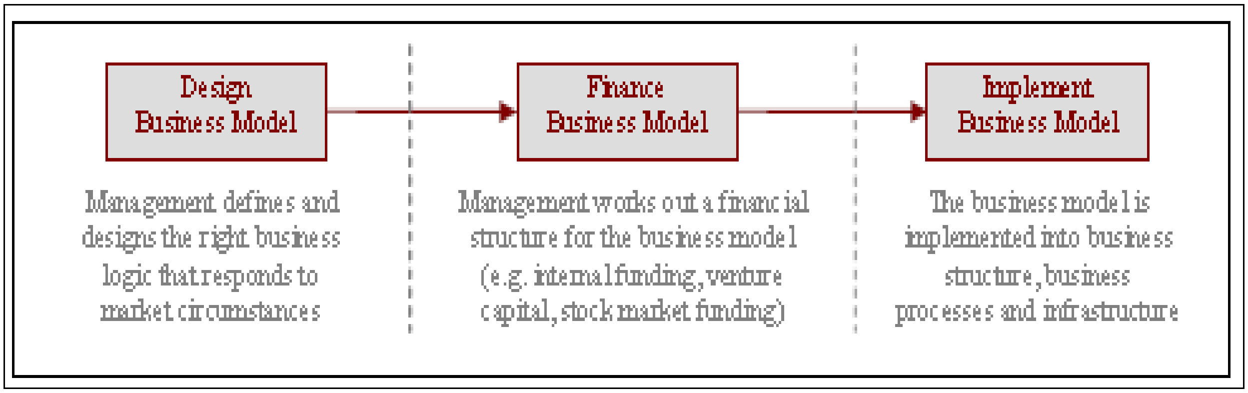


**Figure 2.11:** Designing, financing and implementation of business models (Source: Osterwalder et al, 2005)

**Financing the business model**

Most social enterprises have trouble in raising money as they do not easy fit into either the traditional or for profit model. Foundations and other philanthropists organizations are used to donating money to nonprofit organizations and are often uncomfortable in donating money to organizations which generate profits. Commercial investors on other hand are uncertain about investing in organizations with an explicit social mission. Many commercial investors are also uncertain about investing in social enterprise since they are uncertain about the definition of social enterprise as it may mean different in a large spectrum. The spectrum along with possible financing possibilities is shown in the figure below.

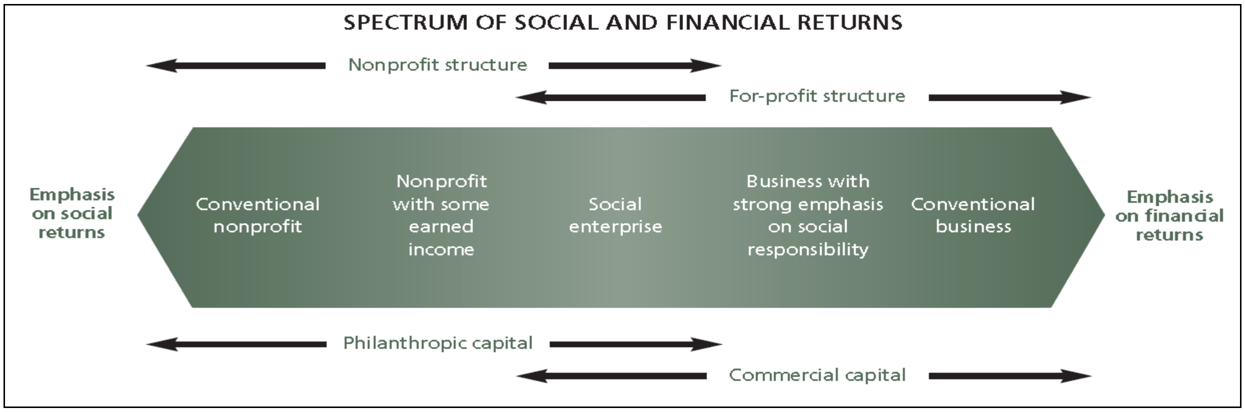


**Figure 2.12:** Range of financing mechanisms for social enterprises (Source: Chertok et al, 2008)

There are different kinds of financing mechanisms available to social enterprises depending on their need. Individual angels, early stage venture capitalists, venture capitalists and investment firms invest in social enterprises with specific investments at different stages of the enterprise like seed stage, startup, first, second and expansion stage or for going public. First source of capital may come from individuals and institutions which invest their own money directly in social enterprises. Second source of capital may come from  intermediates which invest other people's money  and are known as intermediary investors namely angel investors, philanthropic foundations, endowed non profits, international development agencies, international small and medium size enterprise development funds, venture philanthropists, specialized foundations etc (Certo, 2008; Chertok et al, 2008; Linde et al, 2000).

Recently carbon financing through UNFCC CDM mechanism is also used by some social organizations and NGO's.[18] [19] The CDM process has high transaction costs which include search, negotiation, baseline determination, approval, validation, registration, monitoring, verification, certification, enforcement, transfer and registry costs. There are several political risks like if either the investor or the host country does not comply with the eligibility criteria then the CERs generated cannot be used to comply with the mitigation targets; market risks like expected market price of the CERs generated may vary considerably and affecting the revenue of the project. Smaller projects also have higher transaction and up front costs and may get low prices for CER's as CER prices fluctuate by demand and supply. Banks and financial institutions are also reluctant to invest in CDM projects due to long lead times and base lines which may be negatively affected by country's renewable energy policies [20] (Rɪo, 2007).

Furthermore during the running of their venture entrepreneurs must pay attention to the liquidity levels i.e. ability to meet short term financial regulations since low liquidity means that firm is strapped for working capital. They must also watch for leverage levels i.e. extent to which non equity capital is used in a firm and to the long run ability to meet the payments to non equity suppliers of capital. Of course they also need to watch for profitability which refers to ability of the enterprise to generate revenue in excess of expenses and is an indicator for creditworthiness (Wiklund et al, 2008).

**Fit of the business model**

(Morris et al, 2005) discuss the issue of business model internal and external fit. Internal fit ensures coherent configuration of key activities within the firm and external fit addresses appropriateness of the model with external environment conditions. Internal fit is necessary to ensure that a given model is workable. For example a business model with low margin, moderate volume and fixed revenue sources might not be workable. It might be also difficult to develop a business model with large volumes, low costs and high level of customization. External fit ensures that the business model is consistent with changes in the external environment. The business model must be adaptable and in the process some elements can be changed and new elements can be introduced.

Good degree of internal and external fit in the business model ensures that the enterprise will be able to adapt to environmental uncertainty and heterogeneity and temporal differences. Further a business model must be dynamic with flexibility (i.e. exhibit high responsiveness to change) and robustness (i.e. is able to buffer to external changes) which can maintain external fit which can lead to financial, social and environmental performance (Klein, 2008).

In real life however social enterprises can develop specific business models which may be a combination of social as well as commercial business models and the business model might be much more complex than as suggested in the literature due to the varying nature of social enterprises. Some enterprises might have multiple business models thus making it more difficult to understand using standard models. Further social enterprises may use a combination of financing structures for example in form of patient capital, grants from international organizations, self generated funds, venture capitalists, private banks etc thus also making the business model highly complex.

[18] http://www.nextbillion.net/blog/clean-development-mechanisms-for-the-base-of-the-pyramid
[19] http://www.mdgcarbonfacility.org/facility/finance.html
[20] http://www.hedon.info/1352/news.htm

### 2.11.3 Developing human resources and partnerships

Social enterprises find difficulty in recruiting employees and often lack formal human resource policies in terms of retaining and rewarding good people. It becomes difficult for them to retain key talent and skills since they lack legitimacy as an employer and might not be able to offer high compensation to employees. Many social entrepreneurs rely on volunteers and employees who are more concerned with creating social value than gaining economic wealth. Employees are also required to perform multiple roles and duties due to lack of department functions and getting this kind of talent is extremely difficult for them (Cardon et al, 2004; Certo, 2008; Teppo, 2006).

Further during scaling up of social enterprise most social enterprises and clean technology firms face growth mismanagement in terms of management of human resources and often cannot expand beyond a pilot stage due to human resource constraints. Therefore if an enterprise has to scale it needs to focus on building its human resources to administer and accommodate expansion and scaling of the enterprise. This is also problematic as new hires may not have same dedication as the initial team. Scaling up may also incur high costs and administrative expenses while expanding and this may also limits up scaling. (Klein, 2008; Teppo, 2006).

Enterprises need to form partnerships with commercialization partners, distribution networks and get noticed with the right commercial partners. They need to be part of a network where they can have access to the right resources, human resources and information. Social enterprises need to look for actors like NGO's, co operatives, volunteer organizations, universities, research organizations, social institutional players, civil society groups and community organizations.

The enterprise should focus on embeddedness and build upon local customs and develop a local presence with the people by understanding heterogeneity in culture, norms, and traditions. However the relationships should be symbiotic based on mutual trust and not based on client patron relationship to not let middle men exploit people. Such partnerships can be useful for enterprise for market expertise, gaining legitimacy with clients, develop better relationships with civil society and gain access to local expertise and sourcing and distribution systems. The enterprise thus can build upon the intangible assets of the partners like knowledge, brand and reputation and tangible resources like human capital, production and marketing capabilities and access to market. In addition geographic scalability will also depend on whether the organizations they partner with are large and have presence in different geographies since it will reduce the time and effort to find new partners each time they look for expanding in different geographies (Bhagavatula et al, 2008; Dahan et al, 2009; Klein, 2008; Mair, 2006; Teppo, 2006).

### 2.11.4 Gaining legitimacy

Legitimacy may be defined as a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions. Legitimacy enhances both the stability and the comprehensibility of organizational activities, and stability and comprehensibility often enhance each other (Dart, 2004; Niel, 2009; Suchman, 1995).

Three kinds of legitimacy are defined which are built from institutional theory i.e. regulative, normative and cognitive institutions. Sociopolitical regulatory legitimacy or regulatory legitimacy is derived from regulations, rules, standards, expectations created by governments, associations, professional bodies and even powerful organizations. Sociopolitical normative legitimacy is derived from norms and values of the society. An organization demonstrating normative legitimacy addresses norms and values. Cognitive legitimacy addresses widely held beliefs and takes for granted assumptions which provide a framework for everyday routines as well as more specified.

Gaining legitimacy is as important as other resources such as capital, technology, personnel, customer good will, and desirability to survive and grow. It provides a means to overcome the liability of newness and overcome initial failure and setbacks. Legitimacy may motivate the suppliers, partners and investors to take interest in the organization despite the actual uncertainty about the future financial performance of the organization.

There can be several ways of gaining legitimacy. Legitimacy may be built through an organization's historical records of successful product innovation, outstanding scientific reputation, through widely recognized market-based capabilities and through the embeddedness into the local cultural environment. Media exposure, media interviews, publicity, awards, articles in professional magazines are also some of the ways of gaining legitimacy. Alliances to established partners are acknowledged to constitute a primary source of legitimacy in that the company can benefit from the long standing reputation and success of the partner. Entrepreneurs can develop stories about their enterprise i.e. by defining how their venture can lead to sustainable development can lead to gaining legitimacy. However legitimacy building activities can be useful only after some upscaling has happened.

Through all these  legitimacy building mechanism entrepreneurs can influence the government, industry actors, customers and other actors by calling at their awareness and by persuading them of the role, the importance and the usefulness of their innovation for sustainability. However enterprises must focus on maintaining a legitimacy threshold which is unique for most enterprises. Below the threshold level the venture is likely to fail. Once an enterprise crosses the threshold level it is in a better position to further build its legitimacy through proactive steps (Angeli et al, 2009; Teppo, 2006; Zimmerman et al, 2002).

### 2.12 Need for protection of experiments

Due to serious institutional and infrastructural deficits few ventures and enterprises can reach scale. Though it is possible to use the markets to extend access to useful goods and services but few efforts are substantial without long term, broad based impact on social transformation, systemic and political changes with support from the government. Community based projects and decentralized activities will only be successful when they are complemented by infrastructure, social safety nets, redistribution of resources, effective taxation system which are not amenable to privatization. Weak institutions, infrastructure and regime create problems for development of social enterprises and there is a need for government intervention in this regard. Thus social enterprises need favorable protection mechanisms such as enabling infrastructure, business climate (financial systems, security, trade policies, corruption free environment, legal and fiscal framework) and stable political and geo political system. [21] [22] (Klein, 2008; Romijn et al, 2009).

### 2.13 Barriers to upscaling of the experiment

Experiments may face several barriers for up scaling. These barriers may be due to internal issues as well as external factors due to regimes. Barriers due to internal issues may occur due to factors such as lack of finance, lack of distribution channels or lack of human resources etc. Barriers due to regime may be due to unfavorable regulations, excessive support to fossil fuels, lack of political, institutional, economic, social and cultural support etc.Therefore enterprises may face a large number of barriers arising from both the internal as well as external environment

[21] http://www.caseatduke.org/news/1207/Dees_Bloom_Ecosystem.html
[22] http://beyondprofit.com/?p=164

## 2.14 Collective upscaling

The innovation community framework by Lynn (1996); Van de Ven (1993) discusses that the odds of a firm successfully developing an innovation are largely dependent on the extent to which the infrastructure is developed at the industrial community level. This infrastructure facilitates and constrain the entrepreneurial firms and actions of individuals. Firms collectively construct and change the industry infrastructure. This infrastructure is crucial to an individual firm's success at innovation. Further technological innovations do not emerge by a few discrete events performed by few entrepreneurs but by interactions of many actors over an extended period of time.

An individual entrepreneur may not have all of the competences, resources, and legitimacy that are necessary to create this infrastructure for a new business. Entrepreneurs may need to run in packs which mean that entrepreneurs coordinate their actions to simultaneously pursue their self- and collective interests (i.e., simultaneously cooperate and compete with others as they develop and commercialize their new venture). Paths of independent entrepreneurs acting on their own with diverse intentions, ideas can intersect. As the numbers of entrepreneurs gain a critical mass a complex network of co operative and competitive relationships begin to accumulate to produce collective action. This infrastructure includes (1) institutional arrangements to legitimate, regulate, and standardize a new technology; (2) public resource endowments of basic scientific knowledge, financing mechanisms, and a pool of competent labor; (3) the creation and development of markets, consumer education and demand; and (4) proprietary R&D, manufacturing, production, and distribution functions by private entrepreneurial firms to commercialize the innovation for profit. This infrastructure may be developed by superstructure organizations often specializing in coordinating flows of information or coordinating the activities of substructure organizations (Van de Ven, 1993; Van de Ven, 1993; Van de Ven et al, 2006; Van de Ven, 2007).

In the institutional entrepreneurship literature according to Garud et al (2002; Leca et al (2008); Hmimda et al (2009); Weijn et al ( 2007) rarely very powerful actors may possess sufficient resources to impose change on institutional change. Diffusion and legitimization of new institutional arrangements requires the mobilization of support and acceptance from multiple actors. Thus there is a need for collective action from different enterprises or different experiments.

## 2.15 Relationship between upscaling of niches and experiments

The transition studies framework (SNM and MLP) were developed in response to observed limitations of existing tools and policies for environmental innovation. They provide an analytical perspective on management of socio technical transitions towards more environmentally sound socio technical systems. It also provides an analytical perspective for socio technical transitions towards environmentally more sustainable systems of provision. On the other hand the literature on bottom of pyramid, social and sustainable entrepreneurship, development studies and strategic management provide insights into sustainability issues at the micro level i.e. organizational and managerial processes in enterprises, projects, programmes etc. Here the focus is on individual enterprise, projects and little attention is paid to linkages between different experiments as well as transformation of sociotechnical systems. This stream of literature also provides insights into poverty reduction, sustainability, local capacity building, which explore a different dimension of sustainability which transition studies is about to explore. Therefore up scaling of niche and experiments differ in terms of their unit of analysis and focus.

The transition studies and management studies can benefit from incorporating lessons from each other. Transition studies can benefit from incorporating main lessons about organization and management processes, cultural, social, political dynamics at micro level and upscaling at organization level while the management studies can gain insights about macro level issues i.e. factors due to regime and landscape.

The framework developed in this chapter is also capable of explaining upscaling at the experiment level (project dynamics due to management, organizational and institutional factors) as well as at the niche level (context i.e. regime and landscape factors in which experiments take place). However one of the most challenging aspects is measurement of empirical indicators for understanding upscaling at both niche and at level of experiments.

## 2.16 Conclusion and summary of theoretical perspective

The theoretical framework thus built from scientific literature on different topics i.e. socio technical transitions, social and sustainable entrepreneurship, Bottom of Pyramid, strategic management and development studies  provides an understanding of up scaling of niche and experiments in terms of dimensions, indicators and mechanisms. In the next chapter we discuss the methodology and research process. Chapter four and five focus on analyzing real life empirical data and developing inights from the research. This is followed by summary and conclusion in chapter six and recommendations in chapter seven.

# Chapter 3: Methodology and research process

This chapter describes the choices made for the study. It begins with by explaining the philosophical perspective used for the research. Then the research procedure is explained followed by discussion of selection of cases. Then the method of data collection, analysis and development of theoretical insights are also explained. A little discussion is also given about ethical considerations made for the study.

## 3.1 Philosophical assumptions in research

Research methodology is extremely important. Methodological issues arise because research is value driven, influencing the choice of phenomenon and context, choice of method, choice of data and choice of findings. Methodology also requires the researcher to understand ontology and epistemology, research methods or strategies in themselves. Researchers can be enriched by reconnecting the methodologies with their philosophical roots (Seymour, 2007).

According to Arbnor et al (2009); Burell et al (1978); Guba et al (1994); Solem (2003); Voros (2007) formulating a problem, collecting data to a large extent is dependent on methodological view chosen which in turn is also based on a number of philosophical assumptions. Use of any method or methodology for research rests upon fundamental ontological and epistemological assumptions. The ontological question reflects the form and nature of reality and what is there that can be known about it. The epistemological question on the other hand focuses on the relationship between the knower or would be knower and what can be known. It is about acquiring knowledge and understanding and refers to the considerations of what we stand upon for our understanding or questions such as how do we know what we know, why do we believe what we believe or where do we take our stand concerning the opinions on which we claim to believe and to know. The methodological question focuses on how can the inquirer go about finding what he/she believes can be known.

We adopt the subjectivist paradigm i.e. constructivism (knowledge created due to interaction between respondents and investigator aimed at understanding and reconstructing that people including the inquirer hold towards consensus but open to new interpretations) which view the world as socially, politically and psychologically constructed as are human understandings and explanations of the physical world. The knowledge inquirer is both participant and facilitator in the process. (Guba et al, 1994; Patton, 2002)

**Research process**

The central aim of this thesis is to gain a better understanding of the phenomenon of up scaling with respect to PV solar energy in India. However little is known about the issue and thus the research is exploratory in nature and the aim is not to test any hypothesis but to instead develop new theoretical insights about upscaling.

Therefore research in this case is more open ended with development of new constructs and patterns leading to suggestive theory with emphasis to work further on the issues. Thus the focus is on tentative answers to novel questions of what and how i.e. dimensions and mechanism for up scaling of niches and experiments suggesting new insights.

The process therefore involves iterating between data collection and analysis providing the flexibility needed to follow up on promising areas and to abandon lines of inquiry which may not be highly relevant.

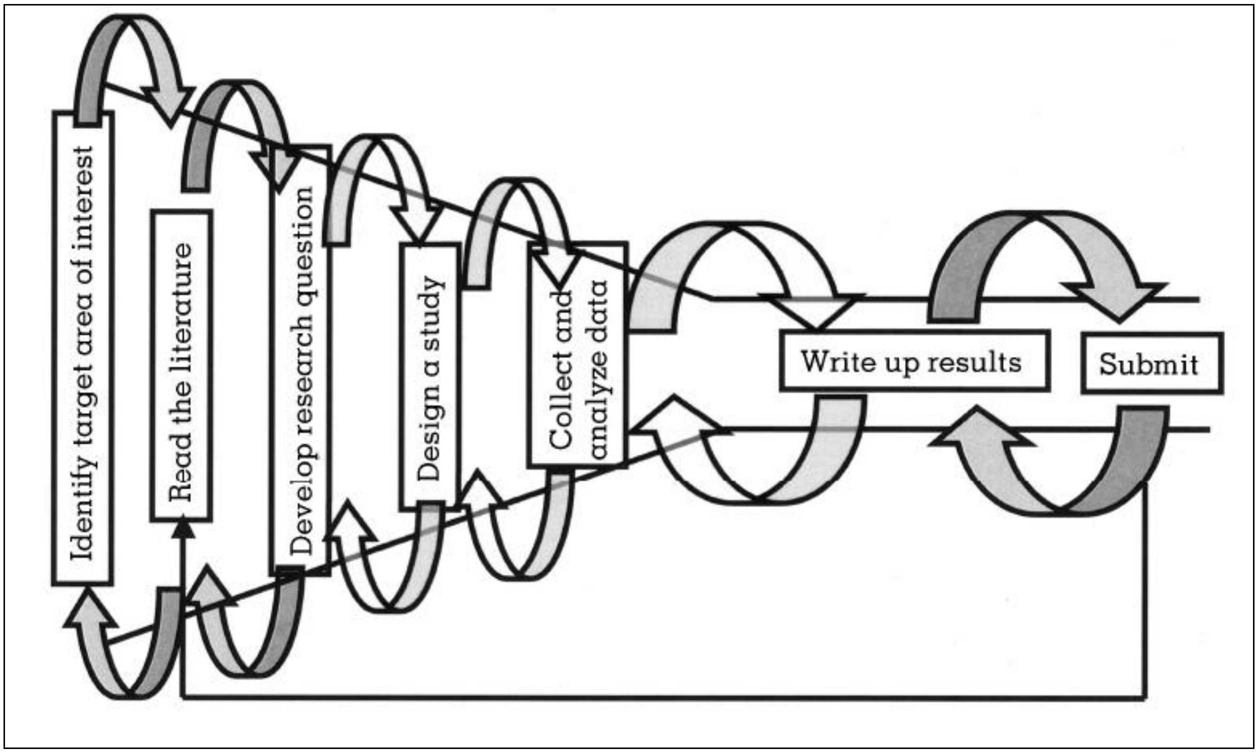


**Figure 3.1:** Field research as an iterative, cyclic learning journey (Source: Edmondson et al, 2007)

The process necessarily starts with some level of awareness of the state of prior work in an area of interest. Researchers can develop a reasonably good understanding of major streams of work in one or more bodies of research literature and then begins to shape a research question. This question substantially narrows down the possibilities for the research design. As the research question becomes more focused, initial research design ideas emerge and are refined and elaborated. As researchers strive to resolve the tension between the ideal version of the research and one that is feasible and viable, the design evolves. During this cyclic process research questions, data collection, theory development are continuously sharpened, revised or even scrapped. Thus the entire research process involves going back and forth between theory, data collection and analysis through bricolage (Edmondson et al, 2007). This research is highly exploratory in nature as the phenomenon of upscaling is researched for first time in detail from a multi disciplinary point of view. Further the research is also open and flexible which allows us to generate new ideas through a feedback and learning process as mentioned above. Therefore we adopt the case study approach for this research due to the high exploratory nature of research.

## 3.2 Introduction to case study methodology

Case study research is an empirical enquiry that investigates a contemporary phenomenon within its real life context especially when the boundaries between the phenomenon and context are not clear (Yin, 2003).Case study research relies on multiple sources of evidence and benefits from prior development of theoretical propositions to guide data collection and analysis. Case studies should also not be confused with qualitative studies. They can comprise qualitative and quantitative studies and case studies may not always have direct, detailed observations as a source of evidence. Case study method is especially appropriate in new research areas with a focus on “how” or “why” questions concerning a temporary set of events over which the researcher has little or no control. A case study has five important components i.e. research questions, propositions, logical linking the data to propositions and criteria for interpreting the findings. Case study research can be carried out by taking a positivist approach or an interpretive stand, deductive or an inductive stand can use qualitative as well as quantitative methods. The case study method also allows room for researcher's subjective and arbitrary judgment than other methods. By contrasting carefully selected cases a researcher can strengthen his or her argument. If the cases are well chosen a researcher can also derive theoretical implications from the case studies.

Further, case studies can be exploratory, explanatory and descriptive. Case studies can be single case design as well as multiple case design. A multiple case design is generally considered a more robust design than a single case study. The main reason for this is that multiple cases provide for the observation and analysis of a phenomenon in several settings. Multiple cases deliver more precise definitions of constructs and relationships and more reliable theoretical propositions but also complicate the research process (Bent, 2006; Dobson, 1999; Meijer, 2008; Raven, 2005; Yin, 2003; Zainal, 2007).

**Case study procedure**

The case study procedure is flexible and the researcher can make a number of adjustments during the process. The flexibility to make adjustments to the research design allows the researcher to probe emergent themes or to take advantage of special opportunities that a given situation may present. If researchers do not make adjustments in case of important discoveries that do not suit the original design, they can be accused of distorting or ignoring data just to accommodate the original design and reporting the data to preconceived notions and ideas. Thus the research strategy is highly iterative and involves learning loops as shown in the figure below in the sense that the researcher can move back and forth between research design, data collection and data analysis. The process is shown in the diagram below.

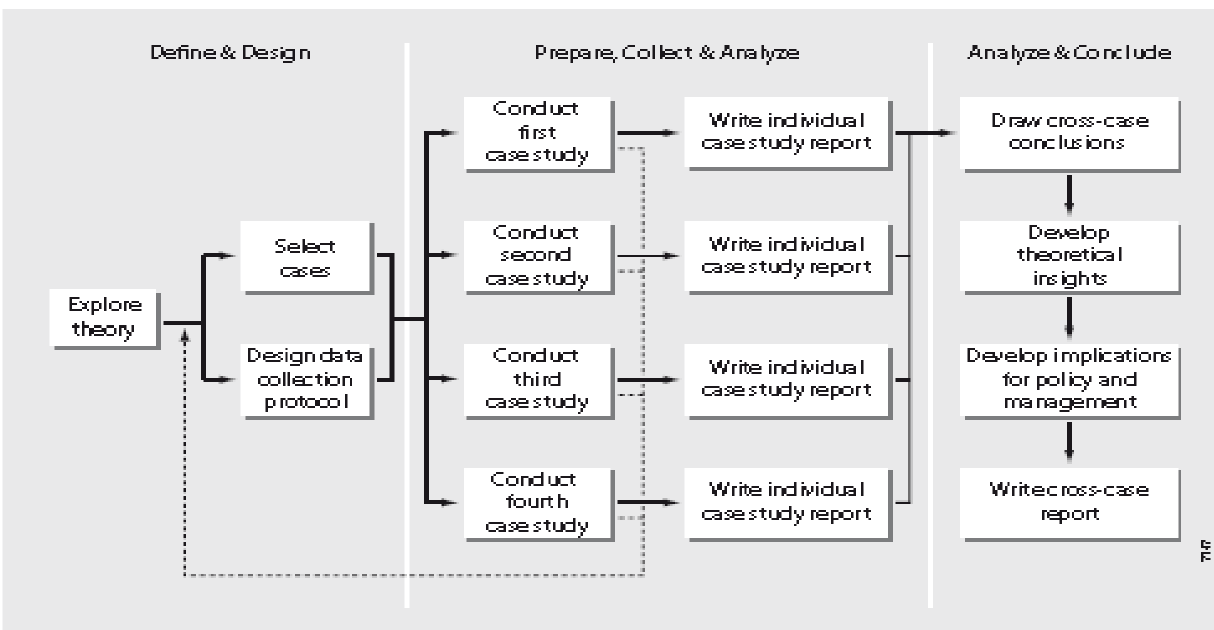


**Figure 3.2:** Case study approach (Source: Meijer, 2008)

Each individual case can consist of a whole study in which the convergent evidence is sought regarding the facts and conclusions regarding the case. Each case's conclusion can be considered to be the information needing replication by other individual cases. For the individual cases the researcher can try to formulate how an individual proposition was developed, demonstrated or not demonstrated in the particular case. While describing the cases the researcher should indicate the extent of replication logic and why certain cases were predicted to have certain results whereas other cases were predicted to have contrasting results. The feedback loop in the diagram above shows that if an important discovery occurs after one of the individual cases i.e. the case did not suit the original design then another feedback loop should focus on redesigning and reconsidering the study's original theoretical assumptions. (Yin, 2003)

Researchers can stop adding cases when a theoretical saturation has reached and the time when researchers experience incremental learning. This saturation also comes with practical constraints such as time and money. There is no ideal number of cases which should be chosen but a number between 4 and 10 usually works well. With fewer than 4 cases it is often difficult to generate theory with much complexity and with more than 10 cases it becomes difficult to cope with the complexity and volume of data (Eisenhardt, 1989).

## 3.3 Data collection and analysis methodology

## Data collection methodology for upscaling of niche and experiments

Case studies can use documents, archival records, interviews, direct observations, participant observations and physical artifacts for data collection. Each of these data collection measures has their own advantage and disadvantages. Documents and archival records are stable, unobstructive, exact, broadly covered and can be reviewed repeatedly but also suffer from reporting bias reflecting personal agendas of authors and at the same time can be not easy to access and retrievable. The use of multiple sources of evidence in case studies allows investigators to address multiple sources of evidence which are relevant and is also helpful in converging lines of enquiry (Winston, 1997; Yin, 2003).

In this study we also maintain a case study protocol as suggested by Yin (2003); Eisenhardt (1989) which focuses on introduction to case study, purpose of research, data collection procedure, names of sites to be visited and contact persons, preparation to be done before visiting the site, case study questions and a guide for case study report. However the research protocol was also modified as suggested based on unexpected situations. Additional adjustments such as addition of questions to an interview protocol or questions to the questionnaire, addition of data sources in selected cases. Modifications in design of case study were also made at times to take advantage of new opportunities. For collecting data we also took several practical issues into account such as collection of data from people during everyday life and not in controlled situations, looking at interviewee's schedule and availability, level of co operation of the interviewee (Eisenhardt, 1989).

Now we describe the data collection methodology for study of upscaling of niche and experiments.

### 3.3.1 Data collection methodology for upscaling of PV niche

The multi level perspective explains transitions as a result of aligning multiple trajectories at different levels. Case studies can be used for describing socio technical transitions, technological innovation journeys, sustainable development as they are better suited to discuss elaborate historical events using qualitative, interpretive methods such as case studies.

According to Coenen et al (2010) analysis using sociotechnical systems approach can be carried out by focusing on System boundaries (based on societal functions and geographically bounded mainly nationally); actors (heterogeneous configuration involving broad spectrum of societal actors and role of societal actors considered autonomous); networks (basic organizational structure between actors) and institutions(regulative, normative and cognitive institutions).The dynamics involved in the sociotechnical systems approach is based on transitions and historical analysis.

For carrying out the analysis we discuss the system boundaries, actors, networks and rules/ institutions. However this may not be highly accurate as in developing nations as discussed by Berkhout et al (2010) making categorical distinctions (experiment/niche, niche/regime, firm/sector) is often difficult because of the mutually constituting and co evolving nature of actors and practices.

In our case actors and network denote actors in the PV value chain, research institutes, government, investors NGO's, consumers etc and the organizational structure between the various actors. Rules/institutions (regulative i.e. regulations, standards, laws; normative i.e. role relationships, behavioral norms and cognitive i.e. belief systems, problem agendas, guiding principles, search heuristics) guide the activities of actors with respect to regulations, belief systems, guiding principles, search heuristics, behavioral norms etc. For studying development of PV niche in India we take a long term historical perspective from 1980's till present i.e. 2010 in which we define the system boundary geographically i.e. focusing on India and by focusing on those actors, artifacts and rules which together fulfill a societal function i.e. energy provision. The reason for choosing the period from 1980's onwards is due to the fact that most of the developments in PV solar energy in India took place from early 1980 onwards. Another important reason was presence of secondary data on development of PV solar energy in India.

For the collection of data for analysis of the niche we focused more on historical and contemporary data.[23] For the analysis of the PV sector in India we mainly focused on journal articles, research papers, industry reports, internet sources etc used. This was done as it was not possible due to research, time and financial constraints to meet all possible stakeholders since this analysis was based on entire nation i.e. India. Thus we relied more on past literature for this analysis.

**3.3.2 Data collection for upscaling of experiments**

## Selection criteria for the cases for upscaling of individual experiments

In this section we describe the selection criteria for the case studies on the experiments. According to Tornroos et al (2005); Winston (1997) selection of cases is also an important task. Selecting cases must be done so as to maximize what can be learned in the period of time available for the study. Case studies should be selective, focusing on one or two issues that are fundamental to understanding the system being examined. The other issue is which actors should be investigated when there are several within the chosen case and which actor has best access to the information. In our case cases were chosen based on discussion in media, news reports, internet, literature, key access to informants. Some important selection criteria were

1.The cases i.e. social enterprises must be in different stages of the PV value chain like installation, servicing and financing, manufacturing etc.The same social enterprise can also be in multiple stages of value chain. Further they should differ considerably in their operating domain, geographical location, business model, ability and potential to meet the energy needs of people at Bottom of Pyramid. They can range from traditional nonprofit, to nonprofit with some income, to social enterprises to social enterprises with commercial motives. They might be using different kinds of funding mechanisms i.e. from grants and philanthropy, to self finance, to social investors, to commercial banks, to commercial investors, like venture capitalist.

2. The social enterprise must be a mission centric enterprise serving people at the Bottom of Pyramid. The enterprise must be some old years old but young enough so that we can meet the founding members or some members involved during the start up stage. It should also have a good reputation with media and local, national and international stakeholders. Another important criteria is that the social enterprise must have background documentation in terms of information on websites, reports and presentations by itself or third parties, description in media in form of news, blogs, web forums dedicated to social enterprises.

[23] http://www.sussex.ac.uk/profiles/228052

3. The social enterprise must have had some sort of success in meeting the needs of the people at Bottom of Pyramid. However it must have also struggled in some respects so that we can derive general pitfalls during upscaling process. The social enterprise and the entrepreneur should also have received some awards and recommendations from credible agencies, international and national bodies or media which can be taken as an indication of the credible nature of the enterprises.

4. The enterprises should have different range of products and services with respect to PV technology, sufficient human resources i.e. ten to fifty employees, management capacity and entrepreneurial talent and good governance mechanisms. They must be also financially sustainable with high liquidity levels, low leverage, strong financial credentials and must have good ability to attract funding for up scaling in future.

5. The enterprise must have potential for upscaling, creating long term social, environmental and economic impact and also bring about institutional change or bring about systemic changes in the society.

Most important with respect to selection of cases it should be possible to have access to informants, establish contact with the enterprise and get an opportunity to visit the enterprises, making observations and conducting interviews. There might be several enterprises which meet the above criteria but there can be several practical barriers to interviewing them like we might not know about all possible enterprises, they might be difficult to reach due to time, geographical and budget constraints and some of them might not be interested in entertaining us due to their personal reasons.

Based on these criteria and practical constraints five social enterprises were selected namely SELCO India, Bangalore; AuroRE, Auroville, Pondicherry; THRIVE energy technologies, Hyderabad; NEST (Noble Energy Solar Technologies), Hyderabad and D. Light Design, New Delhi. We found these social enterprises different in many aspects i.e. in terms of position in PV value chain, business model, geographical location, non profit to commercial status, different stages in upscaling , financing mechanism and meeting needs of people at bottom of pyramid etc.Since we can chose 4 to 10 case studies as discussed before, 5 cases were chosen. With less than 4 cases we would not have generated interesting insights on up scaling due to the complexity and with more than 10 cases it would be difficult to cope with large amount of data. Therefore 5 cases were considered ideal for such a study. However we also believe that there might be several other cases which could have been used for the study.

**Data collection methodology for upscaling of experiments**

For analyzing the enterprises several sources were used. For the data collection with respect to enterprises data was collected over a period of three months i.e. from December 2009 to February 2010 in different locations in south India particularly Bangalore, Auroville (Pondicherry) and Hyderabad. Primary data was collected through interviews and secondary data was collected from the enterprises including websites of firms, business plans, press releases, internal and external reports, educational pamphlets, promotional materials and so on. Further secondary documents were also collected consisting mostly of short case studies and case summaries written by other researchers, organizations and journalists on the social enterprises. Other documents included reports from research institutes, universities, consultancy firms, articles from scientific journals, websites, internet blogs, newspaper articles, and earlier case studies that had been written about the same social enterprises. These provided essential context for interviews which also served as important means for data triangulation. Archival research was done for each enterprise in order to reconstruct historical evolution of each enterprise. Archival analysis included gathering public information on internet, scientific publications, reports and additional internal documents such as presentations in seminars. After carefully studying the documents and the related academic literature we prepared notes which were used as a reference while during the field work.

A field visit was then made to 4 enterprises since D. Light Design could not be contacted for direct interview and most information exchange took place through email. In depth interviews took place with informants from the 4 case studies. Generally we interacted with 1 to 2 informants from each enterprise. We interviewed some important employees with extended periods of involvement with the enterprise and founding entrepreneurs as well who were involved in start up phase of the enterprise. However it was not possible to meet some key stakeholders in the enterprises due to their busy schedule. To conduct the interviews a topic guide was used which listed the most important questions and issues to be covered during the interview. This was done so that during the interview process we did not waste valuable time of the respondent and ask irrelevant questions. The interviews were conducted in a semi structured way in an informal talk. This allowed a large degree of freedom for the respondents so as to come up with explanations in a natural setting rather than planned talk. This helped in following the most important points by having a glance and also facilitated an unbroken conversation. Sometimes no notes were taken during the interview so as to maintain the conversation and no link was broken. This ensured that the respondent did not get irritated by waiting while we made the notes.

Most interviews took place within duration of 30 minutes to 2 hours depending on the amount of available time of the key informants. Generally the initial portion of the interviews emphasized on the history of the enterprise along with challenges they faced till today and during the later part the interview was focused on questions which were directed at thoughts on scaling up process. By visiting the actual sites of the social enterprises additional insights could be gained about how they were really functioning. Direct observations also helped us to note the discrepancies between what was documented about the social enterprises, discussion during the interview and how they were actually functioning. Since up scaling is a highly complex and unexplored phenomenon the interviews could not cover up all issues related to upscaling of the enterprises extensively.

## 3.4 Data analysis methodology

Due to high exploratory nature of research, lack of concrete theoretical frameworks to understand up scaling in the literature, and lack of prior research experience made the entire process messy and quite difficult. The research process was quite complex and involved a lot of learning and feedback using the feedback model by Edmondson (2007). There were instances where we deviated from the original research design in terms of modifying the research focus, research questions, theoretical framework developed in chapter two and method of data collection. This was because during the interviews and data collection process several instances arise where our initial assumptions were not satisfactory. This made us collect data without using a particular theoretical framework as we were not exactly sure as to which constructs will be important and relevant for the research. At times we also had no clear idea about the research and the direction in which it was going which involved a period of frustration and puzzle.

Thus the research process involved a cyclic process of moving forth and back between the theory and data based on new insights during the research. By deviating from the original research based the research process became extremely messed up at times with lack of coherency in the different stages of the research. At times we got lost in the theory and paid too much attention to chapter two and less focus on empirical data but these issues were resolved with feedback. During the learning and feedback process several ideas were left out and new ideas were adopted by scrapping the old ideas i.e. theoretical framework and empirical data resulting in new insights. Several versions of written documents were scrapped in this way as the theoretical framework and data were not fully developed. However this iterative process also lead to development of new insights which are explained later on.

Thus a process of feedback and iteration was involved in the analysis using the theoretical framework and the collected data. For the analysis of the upscaling of niche we moved back and forth between the theoretical framework and data to discuss up scaling of niche. For the analysis of up scaling of experiments the data analysis was carried out by preparing the individual case study reports for different experiments. This analysis was partly theory driven in the sense that the case data was structured and analyzed according to the theoretical framework described in chapter two. This was followed by cross case analysis from different experiments i.e. why certain experiments were predicted to have some results and some contrasting results and development of theoretical insights about up scaling.

## 3.5 Generating theoretical insights from case studies

According to Dubois et al (2010); Eisenhardt (1989); Yin (2003) there needs to be focus on construct validity, internal reliability, external validity and reliability for developing theoretical insights from research. The analysis was inductive in the sense that the analysis aimed to recognize patterns in the empirical data. This was done on the basis of detailed case descriptions for both upscaling of niche and experiments.

## 3.6 Ethical considerations in research process

There are several ethical considerations which need to be considered during the research process. Some important issues are choice of participation for respondents, respect for all persons and points of view, open and reciprocal relationship between the researcher and the respondents. For getting access to the organizations i.e. social enterprises an introductory letter containing our background, description about the research and informal plan about the nature of study was send to each of the enterprises. We also mentioned in the introduction letter that the data collected will be used for academic purposes only. We did not try to hide the identity of the enterprises and decided to openly identify the enterprises so that they may serve as model for future enterprises. We also exercised ethical responsibility by not publicizing or circulating any information which could likely to harm the image of the enterprises interviewed. All the information described in the research was described by taking prior information from the enterprises.

# Chapter 4: Upscaling of the PV niche in India

## 4.1 Introduction

In this section we use the theoretical framework developed in chapter two and methodology discussed in chapter three to discuss upscaling of the Indian PV niche. By using the theoretical framework we first try to develop historical overview of the niche around a period of 30 years with respect to the processes i.e. network formation; articulation of expectations, learning and gaining legitimacy. While development of niches is critical niches alone cannot induce sustainability transitions. In this respect the relevant socio technical regimes and landscapes are also investigated. The analysis also includes a historical review of incumbent regimes, critical regime barriers, niche regime interactions, role of transnational actors and intermediate associations and how niche can up scale. The principle for bounding and measuring niches, regime and landscape need rigorous criteria. However it is always difficult to develop standardized indicators for describing niches, regime and landscape. Thus a more appropriate approach will be to keep a flexible approach while delineating niche, regime and landscape which we also do in our case.

The terms niche and regime are also a matter of empirical definition in terms of scale of practice one is interested and the unit of analysis. In this case we focus more on niche as an emerging PV sector and regime as in the entire electricity and fossil fuel regime in a bounded geography i.e. India alone. Hence this is a 'sectoral' analysis of PV technology in India. The diagram below shows how the analysis will be carried out.

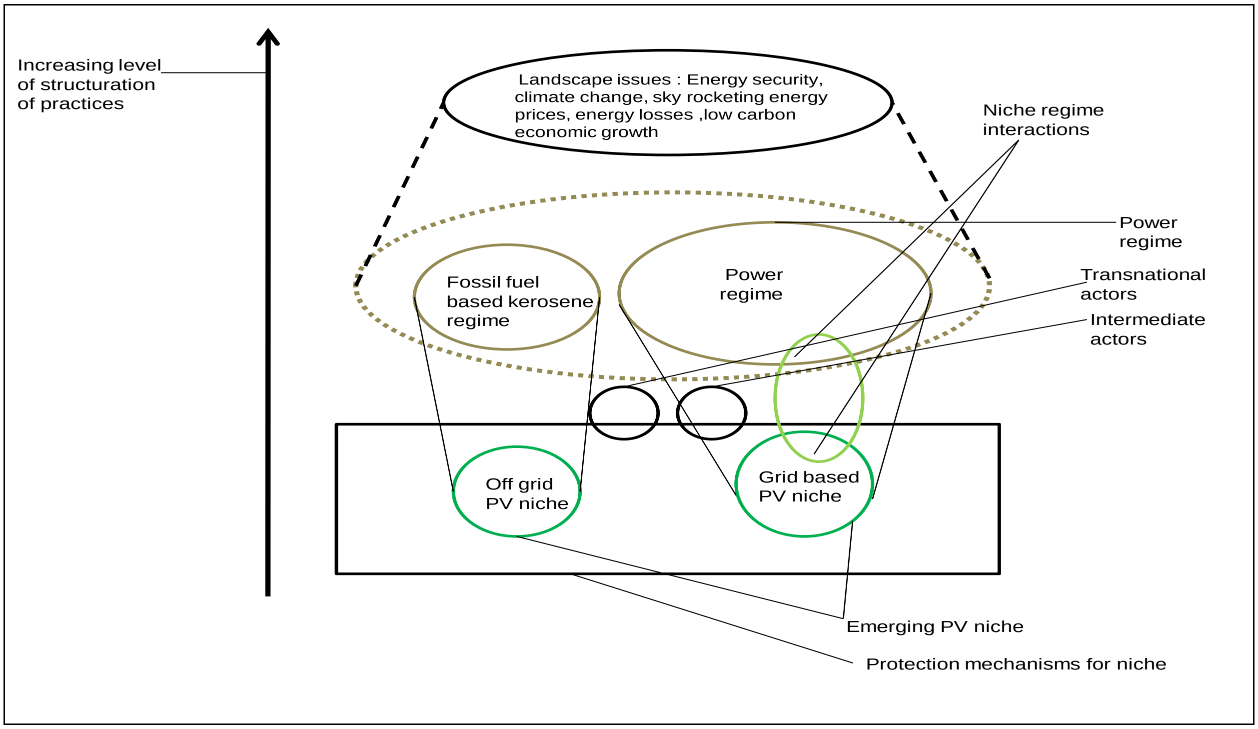


**Figure 4.1:** Representation of niche, regime and landscape with respect to the study (Source: Own interpretation)

The entire analysis is presented in presented in detail in **appendix A** due to large amount of data. There is also an overlap between the data present in the appendix A and this chapter. In this chapter we try to limit to the key issues for upscaling of Indian PV niche and therefore present selective information from the detailed analysis in appendix A. Here we limit the discussion to dimensions and mechanism for upscaling of the Indian PV niche. Since there are large number of barriers for successful upscaling we do not mention them explicitly in a separate section but barriers are mentioned and discussed implicitly in the analysis itself.

## 4.2 Upscaling of the Indian PV niche

Now we discuss the extent to which upscaling has taken place in different dimensions (economic, sociological and sociotechnical) based on the theoretical framework in chapter two and methodology in chapter three. This is the result of ex post reconstruction of the data and analysis. Although we have discussed indicators and measurement techniques for upscaling this analysis does not discuss all of them in detail due to lack of well developed methodologies at present which were mentioned in chapter two. This was due to lack of availability of quality empirical data. Since there have been few past studies related to sociotechnical transitions with respect to PV technology in developing countries there were several challenges in this respect as there was no background literature in terms of transitions studies to follow. The problem became more complex since there have been almost no studies on the phenomenon of upscaling. The major problem was that even if quality empirical data was available it was difficult to exactly fit it with the developed theoretical framework. It was not straightforward to determine which data from the literature corresponds to the evidences and indicators developed for upscaling (economic, sociological and sociotechnical) since the literature contained large amount of information about a number of issues. From all this information it was quite difficult to separate the most relevant data which suits the framework developed in chapter two. The analysis for upscaling of the Indian PV niche therefore became a complicated exercise of interpretation, reinterpretation, personal judgments and bias based on theoretically guided options. This made it practically impossible to operationalize the theoretical framework in chapter two. We also feel that there is a large gap between the theoretical framework and the empirical data which needs to be reduced. We also had to make a trade off between complexity of the framework and empirical data. The present theoretical framework being highly complex in nature makes it difficult to operationalize it with empirical data. However on the other hand if the theoretical framework was made much simpler it would not be able to capture the dynamics of upscaling in detail. We decided to focus more on the complexity of phenomenon of upscaling and therefore the research suffers from lack of fit between the theoretical framework and empirical data.

This analysis and discussion is probably a first step in understanding upscaling and may not be able to capture all kinds of dynamics in detail. Here we suggest that successful upscaling of niche may not take place unless all dimensions of upscaling (economic, sociological and sociotechnical) take place simultaneously. Therefore too much focus on one dimension may lead to problems with respect to development of the Indian PV niche. Another important issue is that upscaling is a global phenomenon and developments in Indian PV niche are dependent on developments in developed nations such as U.S.A, Germany, Sweden, Denmark, U.K. ,Spain, France, Japan, Netherlands etc and emerging nations such as China. For example cost reduction in PV technology in India will be dependent on global developments in PV technology. These issues make it extremely difficult to discuss upscaling in detail. Now we discuss extent to which different dimensions of upscaling have taken place in the Indian PV niche.

**Economic upscaling:** At this moment of time due to rapid developments in the PV industry globally as well as in India and lack of data it is difficult to comment how far economic upscaling has taken place in the Indian PV niche. Here we try to present findings from some latest industry reports. According to Green Peace (2010); IEA (2010) today the vast majority of PV modules (85% to 90% of the global annual market) are based on wafer-based c-Si. The mature technology crystalline silicon with a proven lifetime of 30 years is continually increasing its cell and module efficiency by 0.5% annually, whereas the cell thickness is rapidly decreasing from 230 to 180 microns over the last five years. Commercial module efficiency varies from 14 to 21% depending on silicon quality and fabrication process. The learning factor for PV modules has been fairly constant over the last 30 years with a cost reduction of 20% each time the installed capacity doubles indicating a high rate of technical learning. There is a potential for drastic reduction of the costs due to economies of scale during the following five to ten years. The main challenge for c-Si modules is to improve the efficiency and effectiveness of resource consumption through materials reduction, improved cell concepts and automation of manufacturing. The manufacturing of c-Si modules typically involves growing ingots of silicon, slicing the ingots into wafers to make solar cells, electrically interconnecting the cells, and encapsulating the strings of cells to form a module. Continuous targeted R&D on sc-Si technologies in public and industrial research with a near-term focus can result in a substantial cost reduction and an associated volume effect, both of which are needed to enhance the competiveness and accelerate the scaling up of PV in the next decade.

Further the key technical challenge for PV technology is to reduce the costs associated with PV manufacturing and installation through improved process efficiency and automation, materials improvements, and cost reductions that result from economies of scale, while maintaining or enhancing lifetime energy yields from systems. Manufacturing expansions and efficiency improvements require significant investments. New polysilicon manufacturing plants for example can cost from $500 million to well over $1 billion to build and it has been estimated that the amount required to finance the growth projected through 2012 could range from $15 billion up to $ 67.9 billion. Thus growth and development of indigenous technology, base of skilled human resources, manufacturing capabilities and ecosystem, customer reach out through marketing and sales are critical for the growth of the solar industry in India for both for on grid and off grid applications. Achieving cost reduction with PV technology will require targeted action across all along the PV value chain i.e. (raw materials, module technologies, balance of system components) throughout the lifecycle of product development from basic research to demonstration and deployment. It will also require measures fostering technologies enabling a large scale deployment of PV such as energy storage and grid integration technologies. It is also essential that financial mechanisms are offered across the full R&D spectrum with focus on commercialization. With current developments due to National Solar Mission [24] PV technology and other solar technologies are receiving lot of importance for large scale utility plants and it is expected that by 2030, PV could achieve grid parity thus contributing a significant proportion of India's energy needs [25] [26] (IEA, 2010; Indian Semiconductor association, 2010 ; PV SEMI Group, 2009).

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[24] The National Solar Mission program was initiated by the Government as one of the 8 programs under the National Action Plan for Climate Change by the Prime Minister of India in 2008. In the month of November 2009, the Mission document was released as Jawaharlal Nehru National Solar Mission (JNNSM) and the Mission was formally launched by the Prime Minister on January 11, 2010. The mission has kept two important targets in mind i.e. first to scale up deployment of solar energy keeping in mind the financial constraints and affordability challenge in a country where large number of people still have no access to basic power and are unable to pay for high cost solutions. The immediate aim of the mission is to focus on setting up an enabling environment for solar technology penetration in the country both at a centralized and decentralized level. With current developments due to it is expected that by 2030, PV can achieve grid parity thus contributing a significant proportion of India's energy needs (Indian Semiconductor association, 2010).

[25] http://www.solarfeeds.com/pcs-solar-photovoltaics-blog-/9410-promising-potential-for-pv-manufacturing-in-india--solarcon india-2009

[26] http://www.efytimes.com/e1/fullnews.asp?edid=44758

**Sociological upscaling**: As mentioned before accurate measurement of sociological scaling requires multicriteria analysis and assessment workshops where perceptions of different stakeholders can be analyzed to understand whether the expectations are tangible and converging. However such an assessment was beyond the focus of this research and we are not in a position to accurately discuss the extent to which sociological scaling has taken place in the case of Indian PV niche. From the analysis of the Indian PV niche from the literature we can say that there has been lack of convergence of expectations among the different stakeholders. The government and private market players have focused on large scale grid power plants whereas NGO's, social enterprises have tend to focus more on decentralized solutions for the rural and urban poor leading to two distinct approaches. The approach of private market players has been on increasing the installed capacity of solar energy in India for energy and ecological security and on the other hand the supporters of decentralized solutions have focused on providing energy services for urban and rural poor. [27]

Furthermore the expectations have not been tangible in nature i.e. in terms of robustness and quality and based more on bandwagon effects like commercial opportunities arising from government schemes and recently launched National Solar Mission. [28] [29] There is already resistance from different stakeholders about the National Solar Mission since according to many stakeholders current developments with respect to national solar mission have not been pro poor. The mission allocated only 7 % of the committed subsidy for rural poor in terms of off grid solar plants and lighting systems and targets only distribution of 20 million solar lighting systems by 2022 (Deshmukh et al, 2010).In future therefore there are likely to be issues regarding different visions of different stakeholders leading to problems.

**Sociotechnical upscaling:** Due to lack of empirical data it is quite difficult to discuss exactly the extent to which sociotechnical scaling has taken place in the case of Indian PV niche**.** However we try to describe emergence of intermediate associations and niche regime interactions and anchorage in the case of Indian PV niche.

There has been an emergence of intermediate actors such as Solar India online, Indian Semiconductor Association, Solar Energy Society of India, Renewable Energy Action Forum, Federation of Indian Chamber of Commerce Industry, Semi Conductor Equipments and Materials International. The intermediate actors have been successful in developing knowledge infrastructure to some extent. Though there has been emphasis on development of bureau of Indian standards (BIS) i.e. IS, IP, IEC [30] for various renewable energy technologies yet there has been lack of effective quality enforcement mechanism leading to sub standard products. Most of these groups are quite new and the oldest among them is since 2004 (Ockwell et al, 2009). There are few trade associations such as Semi Conductor Equipment and Materials International (SEMI) for collaborating with Indian semiconductor association to increase public knowledge on solar energy technologies (White et al, 2009). The Federation of Indian Chamber of Commerce Industry (FICCI) also has a task force on solar energy with representatives from the solar energy. The task force comprises manufacturers of photovoltaic cells and modules, systems integrators and power project developers with some important people like The Union Minister for New and Renewable Energy, the Union Minister for Power, the Deputy Chairman of the Planning Commission, the Principal Secretary to the Prime Minister, Secretary, Department of Industrial Policy and Promotion, Ministry of Commerce and Industry etc.[31]

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[27] http://knowledge.wharton.upenn.edu/india/article.cfm?articleid=4437
[28] http://www.indiaenvironmentportal.org.in/blog/indias-national-solar-mission-getting-it-right
[29] http://www.downtoearth.org.in/node/655
[30] IEC denote standards for all electronic, electrical and related technologies set up by International electro technical commission
[31] http://www.thehindubusinessline.com/2010/05/15/stories/2010051551471800.htm

There have also been niche regime interactions i.e. feed in mechanism, purchase obligations and specific laws to promote renewable energy technologies .Though several hybrid actors (MNRE, IREDA, Ministry of Power, NTPC, CERC etc) have emerged there is still a lack of effective anchorage (technological, network and institutional).

The government enacted two necessary major laws, the Energy Conservation Act 2001 and the Electricity Act 2003. Sections 61(h) and 86(1) (e) of the Electricity act 2003 stressed on renewable electricity programmes. The Electricity Act 2003 section 86 required states to set renewable energy targets by ensuring grid connectivity and sale of renewable electricity. The section created a demand for renewable energy by requiring State Electricity Regulatory Commissions to specify percentages for renewable energy for purchased within the area of a distribution licensee. The national tariff policy also required all state electricity regulatory commission to specify minimum percentages for electricity to be purchased from renewable energy sources.

Under the Electricity Act of 2003 it is the central state which has enabling authority for policy, tariffs, grid transmission standards and dispute resolution. However the regulative framework lacks mandatory authority. Indian states are responsible for the discretion involved in regulating private solar capital. So far under the new grid interactive solar policy only few states such as Rajasthan, Gujarat, West Bengal, Tamil Nadu, Punjab and Haryana that have received private capital into initiating tariffs for solar energy and thus becoming eligible for preferential allocations for solar power technology from the MNRE. In 2005 the national electricity policy assured improved access to electricity, power, reliable and quality power of specified standards in efficient manner and reasonable rates, improving commercial viability of sector and protection of consumer interests. In 2006 the government announced integrated energy policy report with aim of providing guidance for India’s energy policy and also the national tariff policy which fixed a minimum percentage of energy to be purchased from renewable energy sources by utilities. In 2008 national action plan for climate change was launched through 8 national missions. The National solar mission focuses on increasing use of solar energy for large scale electricity production, distributed electricity production and development of solar industries. The Government is also in the process of developing a specific renewable energy law. In April 2010 introduction of renewable energy certificates and RPO quotas through central electricity regulatory commission was proposed. In recent times the central government has also delegated certain powers to the States for expediting the implementation of small projects. The State Governments have been encouraged to promote commercial development in the renewable energy sector through policies with respect to banking, wheeling and third party sale of electricity. (APCTT- UNESCAP, 2009; Baker & McKenzie and the World Institute of Sustainable Energy (WISE), 2008; Christiaens, 2008; Singh, 2006; White et al, 2009).

## 4.3 Mechanisms for upscaling of the Indian PV niche (ex post analysis)

The mechanisms for up scaling of the Indian PV niche in terms of different dimensions (economic, sociological and socio technical) are discussed now with an ex post focus. The idea is to discuss to what extent the mechanisms have been used in the case of Indian PV niche so that recommendations can be made for future.

**1.Pressure from landscape**

The landscape factors which led to development of PV niche in India are

1.Security of supply: India has been dependent on fossil fuels in the past. Large scale dependence on imported fuels has imposed a burden on India’s foreign currency reserves and balance of payments. Fluctuations in international oil prices have also lead to risks in terms of security of supply. Other important risks with respect to security of supply are in terms of dependence on import of fossil fuels such as oil from politically instable regions in the world mainly from the Middle East.

2.High green house emissions and climate change issues due to over dependence on grid based electrification from fossil fuels such as coal.

3.Reduction of energy poverty as a large section of India’s population has been deprived of energy services. The Government has recently launched the Jawaharlal Nehru National Solar Mission, which is a major initiative of the Government of India and State Governments to promote ecologically sustainable growth while addressing India's energy security challenge. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change.[32]

**Exerting pressure on regime and decrease in protection mechanisms for regime**

In India high subsidies for fossil fuels has been a historical trend. The Indian government spends approximately USD 19 billion on energy subsidies. Energy subsidies have long been a favourite tool of Indian politicians seeking to win favour in the next round of elections. However an important characteristic of these subsidies is the significant disparity in prices paid by end -users due to cross-subsidisation. Since the energy sector is largely state-owned, the Indian government has historically played a central role in setting energy prices and subsidising various energy sectors. During the 1990s, following an economic crisis, the Indian government began a series of reforms in the energy sector. This included removing trade restrictions and opening up the energy sector to private and foreign investment, in some cases privatization. (Overland et al, 2010; Shenoy, 2010)

Recently the Indian Finance Minister in his annual budget speech put forward the proposal of setting the National Clean Energy Fund which would be constituted through tax levied on coal usage in the country. The quantum of tax would be INR 50 per ton of coal used, which would generate annual revenue of around $600 million.[33] The estimated demand for coal in India in the Budget period is likely to be 440 million tonnes (2010-11) and 518 million tonnes (2011-12) respectively. An extrapolation from this suggests that the size of the National Clean Energy Fund could be anything in the range of INR 22000 million to INR 25900 million respectively for the financial years 2010-11 and 2011-12. This funding will be used for India’s National Action Plan on Climate change.[34]

The price of kerosene was increased by INR 3 against the increase of INR 16-17 per litre based on the recommendation of Kirit Parikh Committee on kerosene subsidies to avoid black marketing of kerosene. The Central government had made provisions in the Kerosene (Restriction on Use, Fixation of Ceiling Price) Order, 1993, issued under the Essential Commodities Act, 1955, to prohibit dealers from selling kerosene at a price higher than the price fixed by the OMCs(State run oil and marketing companies). According to the act state governments in India were empowered to take action against those indulging in black-marketing and other irregularities. However the Petroleum and Natural Gas Minister Murli Deora has admitted that his ministry’s efforts to curb adulteration have failed to achieve the desired results.[35]

The Indian government still has to do a lot in terms of reducing energy subsidies and needs to take strong steps in overcoming vested political interest which resist pressure on existing regimes.

[32] http://www.mnre.gov.in/
[33] http://cleantechnica.com/2010/03/03/india-announces-coal-tax-to-fund-renewable-energy-projects/
[34]http://www.climatechallengeindia.org/component/option,com_content/view,publication/sectionid,26/categoryid,94/articleid,2282
[35] http://www.business-standard.com/india/news/efforts-to-curb-kerosene-adulteration-diversion-failed-says-murli-deora/399771/

## 3. Development of the Indian PV niche

The development of PV niche is discussed in different phases

1.Initial phase: Initiation and demonstration programmes (1980- 1990)

2.Development of a niche market: Commercialization phase (1990 – 2000)

3.Development of PV value chain activities in India (2000-Present)

4.Future developments with respect to India's National solar mission (2010 onwards)

The entire analysis is presented in **Appendix A**.We shift straight away to major findings.

### Summary of the development of the Indian PV niche

From the 1980's till present PV technology in India was confined to a technological niche i.e. for telecommunication, railways, exports and rural energy provision. However with the recent activities in Indian National solar mission it is expected that PV technology in India will become a fully developed market niche. Now we discuss the development of the Indian PV niche with respect to dynamics of expectations, social networks, learning mechanisms, legitimacy and protection mechanisms.

### Shaping and convergence of expectations

The expectations for development of the Indian PV niche over the years have been high. The government with its programmes during the 1980's and 1990's was able to create mass awareness about PV technology which was really beneficial for the development of PV niche. The high expectations also made government provide waste huge amount of subsidies as capital subsidies instead of interest subsidies and focus on creating insfrastructure, financing mechanisms for end users. Also the high expectations regarding development of technology and large scale diffusion as well as commercialization were not tangible in the sense that they did not meet the expectations of users in terms of customization and post sales service. Recently with the Indian National solar mission the expectations are also high and overly ambitious. The government has set high targets of installed capacity of solar power and is providing large number of incentives for project developers. The overly high expectations in the National Solar Mission may therefore create problems such as draining of government huge subsidies in future [36] [37] [38] (Deshmukh et al, 2010).

### Social network formation

The social networks in the Indian PV niche consists of various actors such as government organizations( Ministry of Power, Ministry of Finance, Planning Commission, Ministry of New and Renewable energy IREDA); energy companies; manufacturers and producers of PV equipment (TATA BP solar, Solar Semiconductor, Photon Energy Systems, Central Electronics Laboratory , Reliance Industries Limited, Moser Baer, Maharishi Solar, BHEL, Webel, REIL, Titan Energy Systems, Signet Solar, Velankani Renewable, Lanco Infratech, Sharp, KSK energy ventures, Indo Solar, Central Electronics Limited , KSK Energy, High Hind Vac , Environ Energy systems , Sem India Systems, Bharat Heavy Electricals Limited (BHEL), Lanco Solar; financial institutes (IREDA); research institutes (IACS, IIT Delhi, NPL, IITM, IITKGP, CEL, REIL, Cochin University, Rajasthan University, IISC Bangalore, IIT Bombay, IIT Delhi, TERI New Delhi, IARI New Delhi, NPL New Delhi, Department of Scientific and Industrial research,

[36] http://www.indiaenvironmentportal.org.in/blog/indias-national-solar-mission-getting-it-right
[37] http://www.thehindubusinessline.com/2010/03/05/stories/2010030550750800.htm
[38] http://knowledge.wharton.upenn.edu/india/article.cfm?articleid=4437

Council of Scientific and Industrial Research, Solar Energy Centre (SEC), National Physical Laboratory, National Aerospace Research Bangalore, Indian Academy of Sciences Kolkatta, Gadoid Solar Energy Technologies); NGO's and grass root organizations (Barefoot Engineers, GERES, PEN, Shri Shakti Renewable Energy Technologies, SELCO India, Ramakrishna Mission and the Social Work Research Center).(APCTT- UNESCAP, 2009; Banerjee, 2009; Chaurey, 2001; Indian Semiconductor association, 2010; Ockwell et al, 2009; PV SEMI Group, 2008).

The figure below shows the characteristics of the Indian PV solar value chain with different actors in various parts of the PV value chain.

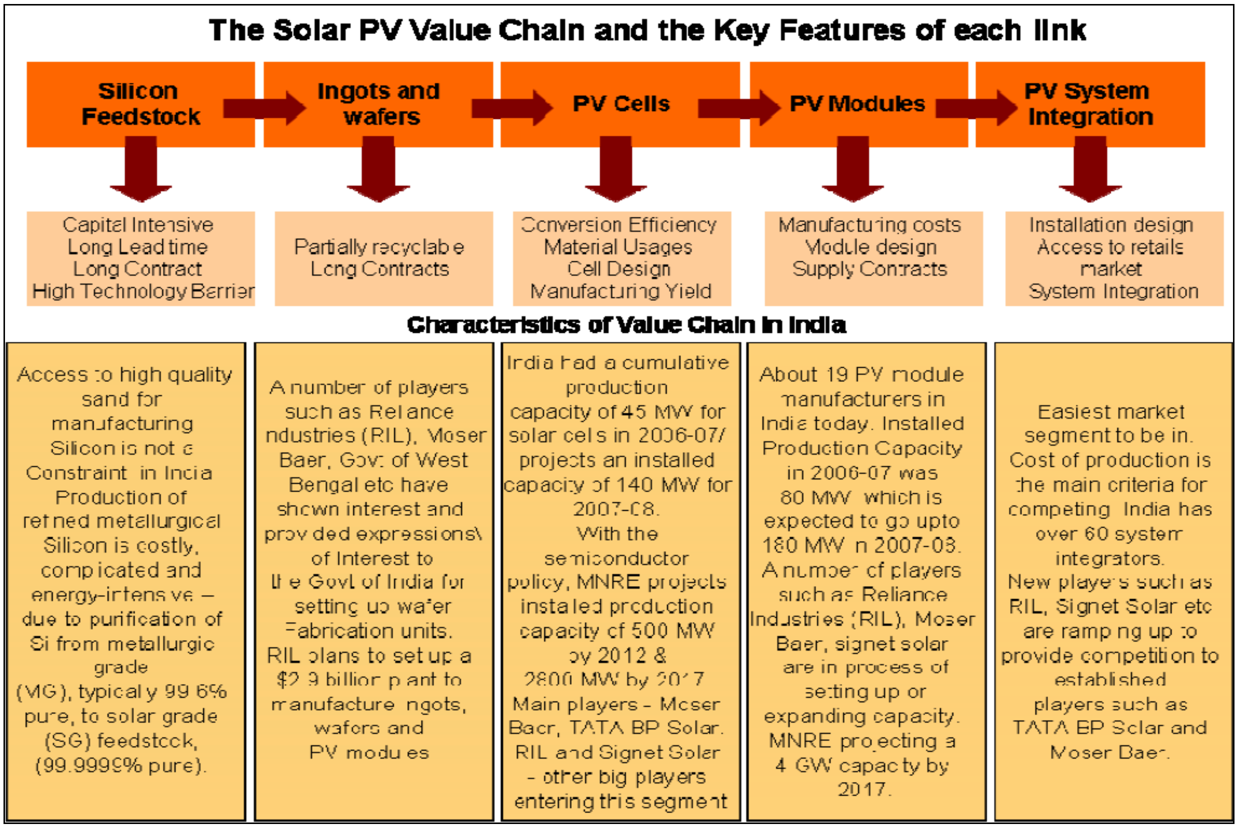


**Figure 4.2:** Description of Indian PV value chain (Source: Indian Semiconductor Association, 2008)

Although the social network in the Indian PV value chain has increased over time but the major problem has been that there has been a huge lack of strong linkages and coordination between the actors i.e. government, manufacturers, research institutes, financial organizations and NGO's and grass root enterprises. This has lead to co ordination failures thus creating problems for successful upscaling.

**Learning mechanisms**

Learning mechanisms in the Indian PV niche over the years have been focussed more on techno economic optimization only but there has been lack of double loop learning i.e. alignment between technical (e.g. technical design, infrastructure) and the social (e.g. user preferences, regulation and cultural meaning) issues. Lack of viable sales or service delivery and maintenance models as well as a lack of trained local personnel to administer repairs limited prospects for a healthy PV market. In terms of meeting energy needs of the poor through devices such as solar lanterns, government schemes failed due to several reasons. The lanterns were non functional due to poor quality supplies made by vendors selected through price driven rather than quality driven government schemes. The size of the lanterns in these schemes was also extremely large which were not appropriately designed to meet user needs. Without understanding for what and how much power, poor people need the government has ended up giving poor people surplus subsidies. Low customer density in many areas made sales, installation, service and payment collection expensive and difficult in centralized government schemes for PV technology .This also reduced affordability of systems. Similarly solar power plants and mini grids run by independent rural utilities and largely funded by central and state government capital have not been commercially viable and neither have been able to meet needs of people [39] (Srinivasan, 2004).Instead most of the learning has been focusseed on low cost manufacturing of PV modules i.e. module stage (figure 4.2) only and has made India as a low cost manufacturing base for PV modules. Recently the focus has also shifted to up gradation to the upper parts of the PV value chain (figure 4.2) i.e. polysilicon manufacturing .The other focus is also on technology and cost point improvements for PV equipment and improving efficiencies of PV cells at commercial scale.

**Gaining legitimacy**

The Indian PV niche has suffered from lack of legitimacy with respect to political debates, support from trade unions, environmental groups, think tanks, support from media and public awareness. In India the environmental movement has been dominated by the aspirations of women, dalits, farmers and the struggles of ethnic groups. The focus has been on problems of social forestry and forest protection (against encroachment and displacement by mining and infrastructure) and with an opposition to genetically modified (GM) seeds and mobilization against urban air pollution, urban toxic wastes and their impact .There has been very little role for energy in general, and solar in particular, in India's environmental movement. The civil society in general is also ignorant about solar energy and activism has been left to small number of active institutions. Think tanks such as the TATA Energy Research Institute (TERI) New Delhi, Centre for Science and Environment New Delhi and World Institute of Sustainable Development have been among the few think tanks but they have not actively contributed to research as they could have done. The print media in India has developed a post-colonial binary narrative, focusing on threats, attributing cause to advanced countries and demanding they lead in both mitigation and compensation to developing countries for their adaptive responses. The print media however has not exposed India's upper income deciles in the high carbon emissions that damage those in the lowest deciles. Further industrial lobbies in India have not represented the interests of manufacturers and labour as well. Trade associations and hybrid institutions of collective action over the years have struggled to establish the legitimacy of solar energy in India.(White et al, 2009).However with the recently launched National Solar Mission as mentioned before the Indian PV niche has started to gain legitimacy but a lot needs to be done in this respect.

4**. Protection mechanisms**

With respect to the protection mechanisms the Indian Government over the years has provided several specific incentives for promotion of various renewable energy technologies. The incentives were predominantly fiscal incentives including direct and indirect tax benefits, renewable energy financing and guidelines for solar power. The government provided direct tax benefits such as accelerated depreciation under section 32 rule 5 of income tax act and tax holiday under section 80 I A of income tax act. The government also provided some indirect tax benefits like duty exemptions and concessions on renewable energy devices. The government initially supported export growth through various measures including duty exemptions on imported material (intended for re-export), subsidized interest rates on working

[39] http://knowledge.wharton.upenn.edu/india/article.cfm?articleid=4437

capital facilities. In January 2009 the government announced significant programs to promote megawatt plus size solar power growth in India. Some of the initiatives were 80 % rebate incentives to solar power projects with no import duty and excise tax on materials for the project. Other benefits are loans for solar power installations, incentives for net metering.[40] (Baker & McKenzie and the World Institute of Sustainable Energy (WISE), 2008; Srinivasan, 2004; Srinivasan, 2007).

The government of India introduced the semiconductor policy initiatives in September 2007.The policy guidelines included a special incentive package scheme (SIPS) (a 20-25 % subsidy for capital costs) for setting up semiconductor fabrication units and also setting up special economic zones and numerous tax breaks. The Ministry for New and Renewable Energy also provided generation based incentives for grid based solar power. However there have been no specific policies to support technological capacity and to encourage collaboration between Indian and worldwide institutions on solar energy. The semiconductor policy included incentive packages for the manufacturing of semiconductors, displays including Liquid Crystal Displays (LCDs), Organic Light Emitting Diodes (OLEDs), Plasma Display Panels (PDPs) and any other emerging displays, storage devices, solar cells, photovoltaics, other advanced micro and nanotechnology products, and assembly and test. Such favourable policies have also attracted many companies. The fabcity in Hyderabad has become a center for solar PV manufacturing. Companies like Sem India and India electronics manufacturing corporation are also planning to set up fabrication units due to the favorable policies (Frost and Sullivan, 2010; Ockwell et al, 2009).

The existing Government polices offer incentives for production (SIPS), generation (GBI , PPA & feed-in tariff) and usage (capital subsidy for certain products) of solar PV technology. The private sector has lined up investments to increase module & cell capacity as well as to set-up solar power plants. With 5 projects for polysilicon planned under SIPS, the solar PV value chain in India will expand to raw material as well. Polysilicon manufacturing capacity will add further strength to Indian solar PV industry. Though polysilicon production infrastructure is a prerequisite for growth of C-Si, the sourcing of technology for the same will be a key issue of concern in this direction. Tax rebates and capital subsidy offered through SIPS enables Indian companies to operate on a level playing field with international counterparts, especially China (Indian Semiconductor Association, 2010). The government recently announced concessional duty of 5 % on equipment required for setting up photovoltaic and solar thermal plants along with excise duty cut to 4 % on CFL lamps. (Networth Capital, 2010).The government announced waiver of duty for solar panels and photovoltaic cells and central excise duty on LED lights was also reduced from 8 percent to 4 percent and clean energy fund for various schemes for solar energy however did not focus much on semiconductor manufacturing and electronic component manufacturing [41] (Sarkar,2010).

However the government has not provided good mechanism with respect to financing of commercial projects. Indian banks have been largely reluctant to lend money for solar energy projects and most initiatives have been taken by public sector or by international development banks and aid agencies. In terms of financing mechanism for users, the general mindset has been use of capital subsidies. The government encouraged adoption through incentive schemes with emphasis on capital subsidies. For example solar lanterns costing around INR 3600 are issued at 50 % subsidy but poor people have been unable to buy them. Flawed financing have hindered many poor people from acquiring solar energy products and services.[42] For the same reasons access to retail finance for investments by final consumers had to be developed by NGO's, NGO- business hybrid models and foreign aid donors (White et al, 2009).

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[40] http://www.renewableenergyworld.com/rea/news/article/2009/03/india-a-vast-market-for-american-solar-pv-companies

[41] http://pradeepchakraborty.wordpress.com/2010/02/26/union-budget-2010-solar-uids-all-the-way/#more-5319

[42] http://business.outlookindia.com/article.aspx?101884

5. **Stable political environment, regulatory support and good governance mechanisms**

In India in the energy sector the responsibilities for governance are divided between the central government and state governments. At the central government level, policymaking and implementation in the energy sector is divided between five different ministries and several government commissions and agencies. State governments have significant responsibilities in the energy sector, especially in the area of electricity. The Indian Parliament is barred from the legislation of certain aspects of the power sector. For the most part the local state authorities are responsible for implementing national laws, but may also pass state laws and regulations for application in their own state Key state level agencies include the State Electricity Boards (SEBs) and the State Electricity Regulatory Commissions (SERCs). In India the state electricity boards have been bankrupted by the subsidy regime, leaving little money for reinvestment or extension of the grid to the estimated 412 million poor without access to electricity. (Overland et al, 2010)

According to Dubash et al (2006); Dubash et al (2007; Dubash et al (2008); Kodwani (2005) the state electricity boards in India historically has been prey to a range of bureaucratic issues. Over time major political issues in the sector have been developed around on farmers hanging on to populist subsidies, industrialists rebelling against the higher tariffs needed to support those subsidies and increasingly affluent and mobilized urban consumers demanding better service. Finance ministers at state and central levels backed by international donors have been limiting subsidies over the years and the state level regulatory commissions have been engaged in resolving these issues. This complex network of bureaucrats is so deep rooted that despite having clear legislative mandate the regulatory governance in power structure is still vulnerable to bureaucratic interference. Therefore the multi party political system, institutional framework which has evolved over the years with embedded distributive politics has created an institutional and political legacy which resists sociotechnical changes.

Similarly the fossil based regime has had effects on the emergence of off grid PV niche. It has been found that rural households use kerosene primarily for lighting and very few households use it for cooking. With increases in electrification the use of kerosene for lighting has fallen to 42 per cent in 2005–2006 from 51 per cent in 1990–2000. The historical patterns of kerosene distribution through the PDS (Public Distribution System) for kerosene has not changed even when there has been an increase in access to electricity. For example 24 per cent of kerosene distribution from the central government has been going to Indian states which have achieved high percentages of electrification and therefore presumably do not need the fuel for lighting. Further reforms to reduce subsidies on kerosene have failed due to strong political pressure and historical distribution patterns. This has also led to two problems i.e. the subsidies have not reached the intended beneficiaries and the misused subsidies have fed the black market economy to influence corrupt bureaucrats and the political system (Shenoy, 2010). Furthermore there has been lack of an interministry dialogue and institutional and political barriers which has restricted the development of the Indian PV niche .This interminsitry dialogue i.e. between Ministries at the central government and state level i.e. chief executive of state renewable energy development agency has also created barriers for successful upscaling of the PV niche in India (Radulovic, 2003; White et al, 2009).

Therefore the unstable political system, vested political interests, incongruence between the national and provincial levels of government that encumbers the implementation of reforms, the poor state of infrastructure and lack of effective regulatory support has created barriers for successful upscaling of the Indian PV niche.

6. **Transnational linkages**: **Role of transnational links and international knowledge flows**

With respect to transnational linkages Indian PV firms were able to acquire research capabilities and knowledge and carry out different activities across the PV value chain .Till recently most Indian firms have acquired technology was through purchasing of necessary licenses or through collaboration with a foreign partner. For example Tata Power, through Tata BP Solar was able to access the knowledge and expertise of BP solar from U.K. Moser Baer PV Ltd. is also working in partnership with Applied Materials, a firm that produces solar cell manufacturing equipment. Moser Baer has also gained significant equity in many US based firms such as Solaria and Stion Corporation. Similarly many firms also acquired technology and knowledge through a large network of Indian scientists and engineers and working abroad. In the past lot of collaboration has taken between Indian and foreign manufacturers through bilateral discussions and Most Indian manufacturers have developed collaborative partnerships ranging from joint ventures to MOU (Memoranda of Understanding) to informal agreements to accessing networks of Indians engaged in PV research abroad. Many firms have also been able to develop technologies through in house R&D. Eg HHV, a firm involved in thin film solar cells developed the majority of its technology indigenously but the entire process took around 10 years. On the other hand Moser Baer was able to start building a thin film power plant in less than 3 years with the help of global linkages (Ockwell et al, 2009). Future activities with respect to the National Solar Mission and development of Indian PV niche are also dependent on transnational linkages.

Furthermore there is a need for collaboration between international technology leaders and firms in developing nations. Collaborations must involve both public and private actors and should be facilitated at the international level with the aim of bringing together technology leaders with interested companies in developing countries. This has to be supported by multilateral and bilateral initiatives such as UNFCCC initiatives for international technology transfer. Apart from that a well defined and enforced IPR legal structure is therefore important to encourage transfer of technology with transfer of skills as well as knowhow for operating and equipment and access to trade secrets. Collaborations should also aim to strengthen links across different sectors of the domestic economy within developing countries, especially industry/ academia/government connections. Joint RDD&D between institutions in developed and developing countries has been identified as one mechanism to build up technological capacity in developing countries. Collaboration in research is growing, at both national and international levels, enhancing the quality of research and increasing diffusion of scientific knowledge. There is also a necessity for linkages between international firms and smaller Indian firms since till now linkages have been initiatives by larger firms who have had access to resources including capital, personnel and global networks (Ockwell et al, 2007; Ockwell et al, 2009; Ockwell et al, 2010).

## 4.4 Mechanisms for upscaling of the Indian PV niche (ex ante analysis)

Till now we discussed mechanisms for up scaling of the Indian PV niche in terms of different dimensions (economic, sociological and socio technical) and the extent to which upscaling has taken place with an ex post analysis. Now we try to discuss mechanisms for upscaling ex ante. However we cannot discuss all possible mechanism for upscaling PV niche since it is hard to determine all mechanisms ex ante. Here we try to bring out the most important points.

First there is a need for much more strict regulatory mechanisms such as carbon taxes, reduction in subsidies on fossil fuels, cess on fossil fuels and using the funds to develop clean energy funds, emission trading schemes through UNFCCC framework etc than which currently exists. Emphasis needs to be paid to implementation of these measures since most reforms and measures often remain on paper and never translate into real work on ground. Second, currently the expectations of different stakeholders in the Indian PV niche differ considerably and large number of new stakeholders have entered due to the high expectations, hypes and hopes created by the National Solar Mission. To counter these issues there is a need for sustainability assessment workshops at national level by the government where views and expectations of the different stakeholders can be discussed at common platforms to avoid conflicting interests in future. Third, protection of the emerging PV niche in India is a delicate issue since there is bound to be discussions and political debates about committing huge public resources to an emerging niche like PV and not other promising niches such as wind, biomass gasification etc. Indian government needs to continuously monitor the progress of development of PV niche in India in terms of economic, environmental and social impact. If there are no significant environmental, social and economic impacts then the protection measures should be reduced and instead used for other purposes in the national interest. Fourth, there is a need for knowledge and capability building and development of PV niche through global networks and linkages. Collaborations with developed nations through international negotiations with increase access to trade secrets and other tacit knowledge will be extremely necessary in the future as currently India lacks knowledge and capabilities about the upper parts of the PV value chain. Last and the most important there is a need for governance reforms and better linkages between the central government and state governments since vested political interests and bureaucratic issues have hindered the successful upscaling of the Indian PV niche.

### 4.5 Summary and Conclusion

We have explained the mechanisms for up scaling of the Indian PV niche. However it is quite difficult to point out the exact mechanisms which can lead to up scaling due to multiple interactions taking place in the transition process at the same time. The factors discussed may be some of the possible mechanisms for up scaling of niche. To conclude we also present scenarios for up scaling of niche. Based on the concept of transition pathways which has been discussed before we develop three transition pathways for the Indian case. These pathways are based on Geels et al (2007); Verbong et al (2010). Since according to Verbong et al (2010) complete replacement of electricity system is unlikely, the technological substitution pathway is not discussed here. Only three pathways are discussed i.e. transformation, reconfiguration and de- alignment and re- alignment.

**Table 4.1:** Overview of different transition pathways for Indian PV niche (Based on Verbong et al, 2010)

| **Transition pathways** | **Main actors in the pathway** | **Motivation for the pathway** | **Characterization of the pathway** |
|---|---|---|---|
| **Transformation** | Centralized and large scale power utilities (New clean coal technologies, carbon dioxide capture, integrated gasification with combined cycle operation);dominance of existing regime actors | Need for rapid economic growth; Need for cost effective and efficiently produced power ; less risk with deployment of established technologies (eg sub critical pulverized coal); slight focus on reliability and environmental issues; commercial prospects due to emission trading schemes etc | Top down centralized approach; dominance of market based instruments; insufficient attention to rural and urban poor energy needs |
| **Reconfiguration** | Centralized and large scale power utilities (solar thermal concentrated solar, photovoltaic plants etc); emergence of hybrid actors; Increasing number of international power firms and outsiders with interest in large scale renewable power generation; new entrepreneurs and small scale market players with interest in grid based renewable power generation | Need for energy security and rapid reduction in green house gas emissions; potential for job creation and growth in new sectors; commercial prospects of large scale renewable energy power generation; potential of large scale (capacity) renewable energy generation in less time span | Top down centralized approach; modifications in institutional framework but dominance of techno economic considerations still prevailing ; insufficient attention to rural and urban poor energy needs due to focus being still on centralized generation |
| **De alignment and re alignment** | Grass root organizations, NGO's, social enterprises with interest in small scale off grid energy solutions (solar home systems, solar lanterns), rural energy service providers, local utility organizations, consumer co operatives, distributed generation utilities, government bodies | Need for energy solutions (reduction of energy poverty) for poor; need for energy reliability, reduced external dependence on fossil fuel regime, cultural and environmental issues and cost effectiveness | Suitable for rural and urban poor; bottom up movement driven by cultural issues and need for reliable energy ; period of competition between various niche solutions; uncertainty about best solution; politics and power issues due to differences in rural and urban energy needs |

These pathways are ideal cases and based on the analysis done. The main motivation behind the analysis is to discuss possible ways in which transformation of the existing regime may take place in India with a focus on main actors leading the pathway, motivation for the pathway and characterization of the pathway. Such an analysis will be helpful in developing future scenarios which are not just based on economic models but based on dynamics in the socio technical systems and different beliefs and motivations of different actors. The grid based PV niche in India is likely to upscale along the reconfiguration and de alignment and re alignment pathway. The reconfiguration pathway is more suitable for up scaling of grid based PV niche and the dealignment and re alignment pathway is more suitable for the off grid PV niche. All the scenarios assume that electricity networks remain necessary in the future however new types of pathways are also possible specially in the context of developing countries. Although the table 4.3 presented above cannot predict the precise development of the future energy regime in India it can provide reflexivity in providing different scenarios by discussing the dynamics of socio technical transitions.

# Chapter 5: Upscaling of experiments in PV technology

## 5.1 Overview of niche experiments in PV technology

In this section we discuss how social enterprises at the micro level can upscale. The analysis focuses on upscaling of five social enterprises which we discussed in chapter three. The social enterprises are SELCO India Bangalore, AuroRE Auroville, Pondicherry; THRIVE energy technologies Hyderabad; NEST Hyderabad, D. Light Design, New Delhi. In this section we discuss each of these social enterprises according to the framework developed in chapter two and methodology discussed in chapter three.

We discuss each social enterprise in the following format

**Table 5.1**: Methodology used for description of case studies (Source: Own interpretation)

| **Section** | **Description** |
|---|---|
| Introduction | This section provides basic information about the social enterprise |
| Background information and history | This section provides an overview of the history of the enterprise to present a context in which we can discuss upscaling |
| Mechanisms for upscaling | This section describes the social enterprise with respect to<br>1.Vision, mission and expectations<br>2.Learning in terms of development, financing and implementation of business model; fit of the model<br>The business model is described in terms of (products and services, infrastructure management, customer interface and financial aspects)[43]<br>3.Human resources and partnerships<br>4.Gaining legitimacy |
| Barriers to upscaling | This section describes the barriers which the enterprise faces in up scaling |
| Dimensions of upscaling | This section describes how far the social enterprise has upscaled in different dimensions[44] |
| Conclusion | This section provides a conclusion of the individual case study on the social enterprise |

The detailed analysis of all the enterprises is presented in **Appendix B** in the format presented in table 5.1.In the analysis of the different case studies in this chapter we do not make categorical discussions between dimensions, mechanism and barriers for upscaling but deal with all of them together to make the discussion more streamlined for bringing out the most important insights from the different case studies.

[43] In the description of business model the detailed financial model of the enterprise nor its financial stability in terms of profitability are not explained as these aspects are difficult to discuss due to confidentiality reasons as well as rapidly changing nature of financial indicators with respect to time.

[44] Scaling in terms of impact is also not discussed accurately as it requires a fully fledged impact assessment of the enterprise which is beyond the focus of this research. Moreover as mentioned before, impact measurement tools for social enterprises have not been standardized till now and this makes it difficult to discuss scaling of social impact

## 5.2 Analysis and key characteristics of cases studied: Findings from cross case analysis

From the analysis we found out that there is no dominant way of upscaling and enterprises have pursued up scaling in different dimensions. All the enterprises have adopted a hybrid model with strong social, environmental and economic drive. The individual cases were taken together and analyzed resulting in summary of findings.

**Table 5.2**: Extent of upscaling achieved in different dimensions for the five case studies [45] [46]

| **Enterprise**<br><br>**Dimension of up scaling** | SELCO | AuroRE | Thrive | NEST | D.Light Design |
|---|---|---|---|---|---|
| Quantitative | ++ | ++ | ++ | ++ | +++ |
| Net impact [47] | +++ | +++ | +++ | +++ | +++ |
| Organizational | +++ | + | +++ | ++ | +++ |
| Geographical | + | ++ | +++ | +++ | +++ |
| Depth | +++ | +++ | +++ | ++ | +++ |
| Functional | +++ | +++ | +++ | +++ | +++ |
| Replication | +++ | +++ | +++ | ++ | ++ |
| Innovation | +++ | +++ | ++ | +++ | +++ |
| Value chain | + | + | ++ | +++ | + |
| Institutional | ++ | + | + | + | + |

**Explanation**: High upscaling performance: +++; Medium upscaling performance: ++; Low upscaling performance: +

[45] This table presents an overview of how far different enterprises have scaled in different dimensions (based on chapter two). This is based on historical analysis of the enterprises using case studies and analyst's interpretation. This table can also be used for comparison between different enterprises in same dimension as well as comparison of the same enterprise in different dimensions. The table only presents a probable measure of upscaling in different dimensions with three indicators (High upscaling performance : +++; Medium upscaling performance: ++; Low upscaling performance: +). Regarding net impact since we are not in a position to measure the impact we decide to give high scalability to all enterprises based on historical records. Furthermore these indicators can change rapidly with respect to time and are also likely to suffer from lack of accurate data, analyst bias and inaccuracies in analysis.

[46] The detailed analysis of each case study is mentioned in Appendix B.

[47] In our case we could not exactly measure the net impact of the enterprises as mentioned before as such an exercise was beyond the scope of this research .Therefore based on archival data, reports by credible organizations on the enterprises we decided to give high upscaling performance to all the enterprises in this dimension

**Table 5.3**: Description of upscaling performance with respect to the dimensions (Source: Based on own interpretation) [48]

| **Dimension of upscaling** | **High upscaling performance** | **Medium upscaling performance** | **Low upscaling performance** |
|---|---|---|---|
| Quantitative | Potential of reaching hundreds of millions of people | Potential of reaching millions of people | Potential limited to hundred thousands of people |
| Net impact [49] | Potential for significant social, environmental and economic impacts | Potential for moderate social, environmental and economic impacts | Potential limited to low social, environmental and economic impact |
| Organizational | Potential of employing thousands of employees in different departments ;multiple offices and manufacturing facilities ;large number of investors and funding sources etc | Limited to hundreds of employees; few offices and manufacturing facilities; limited number of investors and funding sources | Limited to less than hundred employees ; confined to one office and manufacturing facility; one or two major investors and funding sources |
| Geographical | Potential of reaching large number of nations (more than 10) apart from home country; presence in more than 10 different states in the home country | Potential of reaching upto 10 countries apart from home country ; presence in upto 10 different states in the home country | Limited to reaching few countries but mostly limited to the home country; presence limited to few states in the home country |
| Depth [50] | Potential of reaching people at the bottom of the Bottom of the Pyramid (earning less than USD 2 per day, PPP) | Limited to reaching people at the middle of the Bottom of the Pyramid (earning between than USD 2 and 5 per day, PPP) | Limited to reaching people at the top of the Bottom of the Pyramid (earning more than USD 5 per day, PPP) |
| Functional | Potential of developing more than 10 different products and services | Potential of developing upto 10 different products and services | Potential of developing only 4 to 5 major products and services |
| Replication | Potential of creating and incubating thousands of new entrepreneurs | Potential of creating and incubating hundreds of new entrepreneurs | Potential of creating and incubating upto hundreds of new entrepreneurs |

[48] The descriptions in the table for high, medium and low upscaling performance are based on personal interpretation, literature review, interviews and insights from empirical data. The term potential signifies the capability of development, possibility into actuality in the future based on historical trends based on archival data

[49] This requires impact assessment exercises.Eg. http://blog.acumenfund.org/author/khill/

[50] Based on (George,2009)

| | | | |
|---|---|---|---|
| **Dimension of upscaling** | **High upscaling performance** | **Medium upscaling performance** | **Low upscaling performance** |
| Innovation | Presence of specialized R&D centers and innovation department with full time employees dedicated to innovative activities ; large number of patents, scientific publications and knowledge dissemination activities in the media | No specialized departments for innovative activities such as research and development; few patents, scientific publications and knowledge dissemination activities in the media | Limited innovative activities such as research and development ; almost no patents, scientific publications and knowledge dissemination activities in the media |
| Value chain | Potential of presence in more than 3 stages of the external value chain | Potential of presence in one or two stages of the external value chain | Potential limited to one stage only of the external value chain |
| Institutional [51] | Potential of bringing in powerful social change ,destabilizing existing institutions and replacing them with socially efficient ones | Potential of modifying few existing institutions (regulative, normative and cognitive) | Limited potential of modifying existing institutions (regulative, normative and cognitive) |

Before bringing out the key insights from the analysis of the different case studies we would like to bring out some important issues. Since upscaling is a complex and multifaceted phenomenon it is quite difficult to address it in an objective and systematic manner. Different practitioners and academics can have different definitions of upscaling based on their personal interpretation, knowledge and experience. Table 5.2 regarding the extent of upscaling achieved in different dimensions in the five case studies is based on table 5.3 which describes the criteria for providing different indicators (+++ ; ++ ; +) i.e. high, medium and low upscaling performance for the five case studies. However the tables (5.2 and 5.3) are based on personal interpretation and lack objectivity. Some other issues associated with them are lack of accurate empirical data, highly subjective in nature, based due to analyst's interpretation and rapidly changing with respect to time.

The indicators given to different case studies were based on archival data of the change processes in the different social enterprises. The analysis was retrospective in nature i.e. the study was conducted after the outcomes were already known to us. However knowing the outcomes of the process of upscaling also biased the results since we also filtered out data which did not fit in with the research objective and the framework. It would have been better if we would have conducted the study in two different intervals of time (e.g. with a year gap) as a change process in real life as upscaling takes place. This could have led to much better analysis. Another important issue is that we could just manage 30 minutes to 2 hours of interview time due to lack of familiarity from the key stakeholders in the enterprises and could not ask

[51] Based on (Zahra et al,2009)

them in detail about upscaling in different dimensions. Moreover we came up with the refined theoretical framework after the field work due to the iterative nature of research as discussed in chapter three. Hence we were also not in a position to exactly ask them the extent to which upscaling had taken place in their specific case. Further due to lack of time, budget and other constraints we were also not in a position to conduct a follow up study. Another way to deal with the issue is to conduct workshops with stakeholders from the different enterprises where they can rate their enterprises themselves and also get rated from other stakeholders i.e. perceptions of other stakeholders about their enterprise. Such workshops can provide better insights about upscaling but are extremely difficult, time consuming and expensive to conduct. Most important our research was guided by theoretical intentions which are quite different from the dynamics the stakeholders in the different enterprises interviewed were facing in their daily lives. We may also have missed the dynamics confronting their minds during the interviews leading to different interpretation of upscaling than perceived by them.

Some important conclusions from the case studies on experiments i.e. enterprises are

1.Upscaling for social enterprises in the literature and practice as well has been focused in the past on few dimensions such as quantitative i.e. number of beneficiaries, functional, organizational or even geographical. Among these dimensions quantitative dimension has been frequently used since it is the most simple to measure as well as can be used easily in practice. However from the analysis it was found that it is necessary to move from this narrow conceptualization of upscaling to a more holistic way of understanding upscaling i.e. looking at upscaling from different perspectives and dimensions as discussed in the research as mentioned in tables 5.2 and 5.3.

2.Upscaling is primarily driven by the vision, mission and expectations of the enterprises. For example SELCO aims for customized energy solutions and is very focused on need based solutions. Therefore it is not likely to scale as aggressively as D Light Design which focuses on meeting the energy needs of large number of beneficiaries. On the other hand NEST is very focused on providing high quality products and is not likely to reduce its quality standards for lowering the costs which make its products unaffordable for the extreme poor. Therefore ideology of the entrepreneurs and their vision plays an important role in upscaling.

3. Upscaling only takes place successfully when the enterprises are financially sustainable. Enterprises looking to scale quickly without developing a viable and mature business model and not looking at their financial viability in the long run are likely to fail. Sometimes it may even take years to make a model work. For example SELCO had to struggle for more than 5-6 years to develop a viable model. Similarly all enterprises in the past have struggled to develop viable models. Developing a viable model requires learning in the form of double loop learning where enterprises need to develop model which are financially self sustainable and not dependent on external grants and subsidies.

4. Upscaling also requires local capacity building and building on the existing knowledge and assets of the poor. All the enterprises in the case studies built upon local knowledge and assets. Therefore for up scaling enterprises need to develop products and services i.e. create a strong value proposition which takes the local knowledge, customs and needs into account.

5. There is no one dominant way of upscaling. Enterprises can pursue up scaling in different ways which has been discussed in detail in Appendix B. We found out that different enterprises up scaled differently in different dimensions depending upon several factors such as vision, business model, human resources, legitimacy etc which is also evident in table 5.2.

6.Developing partnerships and social networks though important will be useless unless it is complemented by good human resources. Lack of human resources is perhaps the primary factor which limits upscaling. This is because when enterprises need to scale from small pilot projects in the beginning, specialized skills need to be developed in all areas such as management, finance, technology, operations, sales and marketing etc. At this moment the innovation just does not need to be supported by a network of actors but needs to be developed as a viable business. There is a need to understand the 'tipping point' when a pilot project turns into a viable business. If specialized human resources are not developed then the original idea just remains a pilot project and never reaches scale.

Developing good human resources in social enterprises is more difficult and challenging than even multinational enterprises. This is because there needs to be a good mix of people who are highly experienced and trained in different areas such as technology, finance, supply chain, operations and management systems with a combination of local people who are not trained and not even educated at all Areas such as after sales services and distribution in locations where people from Bottom of Pyramid. live requires deep knowledge of local customs and culture which is largely unavailable with highly trained management staff. Therefore the management of the enterprises need to invest a lot of time, energy and resources in training local people without which the enterprises may not be successful. Another important challenge is to get good human resources at extremely low salaries. The biggest challenge is that even when highly trained people are ready to join, they might not be interested due to low salaries which social enterprises may not be able to offer. On the other side if social enterprises offer very high salaries to trained people they are at risks of becoming financially unsustainable.

7. It is important to choose the right financing structure based on the business model and motivation of the enterprise. In the case studies enterprises have used a range of financial measures such as grants from international organizations and government bodies to social investors to private investors to venture capitalists. Therefore for up scaling, finance plays a critical role but the important point is that it must fit with the motivation, expectations, style of working and business model of the enterprise. In this respect social investors such as Lemelson foundation, E+CO, Acumen fund may suit enterprises which are looking for organic scaling i.e. a slow and steady process whereas venture capitalists such as DFJ (Draper Fisher Juvertson) may be more suitable for enterprises looking for aggressive growth and scaling.

8. Innovation is extremely necessary for upscaling. By innovation we mean dynamic capabilities to come up with new products and services suiting needs of users, innovative means of financing for users as well as research and development for developing new products and services or even improving the performance of existing products and services. All this requires innovation for years in the form of double loop learning. Therefore enterprises failing to innovate may not upscale significantly. All enterprises studied in the case studies have focused on innovation and this is a major reason for successful upscaling to some extent.

9. Enterprises need to develop a business model which is mature (i.e. stands the test of time), fit (external and internal) and is able to deal with environmental uncertainty and heterogeneity in low income markets. The business model must be flexible and robust to adapt to different contexts and situations. Therefore lack of maturity, fit, robustness and flexibility would make it difficult to upscale.

10. Enterprises need to focus on developing dynamic core competencies. A firm's core competence(s) is defined as a set of problem defining and problem solving insights that fosters the development of strategic growth alternatives. The term dynamic refers to the capacity to renew competences so as to achieve congruence with the changing business environment. The term capabilities emphasizes adapting, integrating, reconfiguring internal and external organizational skills, resources and competences to match the requirements of a changing environment. Core competences are developed from organizational

learning. For core competences to be effective they must be continuously evolving and changing via continuous organizational learning. Core competences thus cannot remain static and firms need to upgrade their competencies to create new alternatives. Further core competences based on double loop learning (development of heuristics, cognition and insights required to solve complex problems) lead to specialization and are highly difficult to imitate. Dynamic core competences can be leveraged to create alternatives in terms of products and services, new applications of existing technologies and new businesses.

All the enterprises in the case studies have developed core competencies through double loop learning. These core competencies have been leveraged to create alternatives in terms of new products and services, new applications of existing technologies and new businesses over the years. For upscaling these competencies need to be nurtured and upgraded in order to build new competencies. Therefore for successful upscaling, value propositions need to be developed continuously for people at the Base of Pyramid by focusing on dynamic core competencies.

Another important aspect is that new start ups interested in energy services for the BOP cannot replicate the enterprises discussed. This is largely because these enterprises have upscaled largely due to their dynamic core competencies. Core competencies are hard to imitate since they are proprietary to the enterprise. New enterprises can either develop strategies from a combination of strategies used by enterprises discussed or adopt an approach developed by them alone or even a mix of both the approaches.

11. Enterprises need to develop appropriate business models through double loop learning if they are looking to focus more on quantitative and geographical scaling i.e. increasing number of beneficiaries since certain business models may not allow high upscaling in this dimension. For example SELCO's business model does not fit well with rapid quantitative scaling since it has a service model which is based on customized solutions in a particular geographical region unlike D Light which has a product model which makes it easier for D Light to develop high volume low cost products which it can distribute to a large number of people in different geographies. This can be seen in table 5.2 by comparing SELCO and D Light.

12. Enterprises will find it difficult to scale deep (tables 5.2 and 5.3) i.e. reach increasingly poorer segments of the population unless they are supported financially through government grants, carbon finance through UNFCCC mechanism and support from international financial institutions. This is because commercial approaches though successful may not reach the extreme poor i.e. those without any kind of assets who cannot be offered microfinance loans due to lack of assets.

13. Enterprises not interested in scaling organizationally i.e. expansion of the original enterprise can upscale by replicating themselves by creating and supporting new entrepreneurs. Creating new entrepreneurs is very important since social enterprises with lack of human resources and commercial capital may not be in a position to expand themselves but they can 'replicate' their work by creating and supporting new small rural entrepreneurs and provide them with income generation activities.

14. Value chain upscaling i.e. moving up the PV value chain for enterprises requires a balancing act. Only two enterprises i.e. NEST and Thrive have upscaled in this dimension.(table 5.2). This is also risky in the sense that the expertise acquired in processing silica and manufacturing modules (upper parts of PV value chain) may not lead to expertise in balance of systems, installation and maintenance services, consumer financing, sales and marketing (lower stages of PV value chain) and vice versa. Enterprises must be very careful while doing this since they need to acquire additional capabilities, capital and human resources in being a player in all the parts of the value chain.

15. Upscaling requires patience, time, resilience, flexibility and persistence on part of the enterprises.[52] Small organizations starting from scratch may take around 10 to 15 years or even more to reach a significant scale. Attaining scale is therefore a difficult, costly and time consuming process. With respect to time we found some interesting patterns. Most of the enterprises have scaled organically taking a considerable amount of time i.e. around 10 years with SELCO being almost 15 years old. However D Light Design is an exception. It has been one of the fastest growing enterprises and has reached large number of people i.e. around one million in a very short span of less than 4 years. This may be also due to the fact that D Light came onto the scene in 2006 when solar energy infrastructure in India had developed to a good extent.

16. Most of the enterprises discussed have taken pro active steps in enhancing their legitimacy. Some common strategies have been establishing alliances with a range of local, national and international stakeholders, enhancing embeddedness into local cultural environment, certifications from international bodies, media exposure through interviews and knowledge dissemination activities and awards from professional bodies. Almost all of the enterprises have benefitted highly from global and transnational linkages. There is also an interesting fact that all the enterprises are more known internationally than in India. By enhancing their legitimacy the enterprises have benefitted in terms of new stakeholders and networks for further upscaling, getting access to finance from various international organizations as well as sources of knowledge for universities globally and attracting student interns from the best universities all over the world.

17. Institutions and the policies that shape them are also crucial to upscaling. Therefore entrepreneurs need a supportive infrastructure which includes financial, human, intellectual, social, and political capital.[53] [54]. Supportive government policies must be designed in a way that social innovations are not misused by people for personal gains and social entrepreneurship is not destructive or unproductive.[55] (Bloom et al, 2008; Karmachandani et al, 2009; Minniti, 2008)

18. Institutional upscaling is beyond the reach of individual enterprises and requires collective action from a critical mass of entrepreneurs. As it can be seen in table 5.2 that all enterprises except SELCO score low in this respect. All the enterprises discussed found it difficult to scale institutionally. Some of the key barriers have been high subsidies for fossil fuels and high taxes for solar energy products, lack of consumer finance from financial institutions and other regulative barriers. Most enterprises have advised government officials and even lobbied against high subsidies for fossil fuels but their efforts have not resulted in any major institutional changes. Enterprises have also found it time consuming to engage themselves in trying to bring in institutional changes since this may make them lose focus from their primary work i.e. day to day functioning of the enterprise and meeting the needs of their customers. Furthermore even though a critical mass of entrepreneurs lobbies, government is unlikely to change since deep rooted cognitive structures i.e. taken- for- granted beliefs and structures and the ways in which bureaucrats and politicians work at all levels (national, regional and local) are very difficult to change even if regulative institutions are modified.

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[52] http://www.nextbillion.net/blog/2008/06/04/guest-post-radical-transformative-unreasonable-extreme-leap-frog
[53] http://beyondprofit.com/?p=164
[54] http://www.caseatduke.org/news/1207/Dees_Bloom_Ecosystem.html
[55] http://www.india-seminar.com/2009/593/593_vijay_mahajan.htm

## 5.3 Collective upscaling

Groups of social enterprises can realize their collective interests and collective knowledge can be developed by intermediatary actors like social foundations, finance networks, entrepreneurship networks, web forums, research institutes, professional societies etc. They can help to promote practices, standards, common agendas and learning experiences among new entrepreneurs from the experiences of established entrepreneurs. The intermediatery actors can be useful in creating, maintaining and distributing knowledge collective knowledge.

It has been found that there are several organizations such as the Ashden Foundation awards for sustainable energy, Confederation of Indian Industry, Ashoka, Lemelson Foundation, Schwab foundation, UNDP, Global Village Energy partnership (GVEP), Clean Tech India, USAID South Asia Regional Initiative for Energy, Skoll foundation, REDCO alliance, ESAMP, World Economic Forum etc which have played an important role in developing collective knowledge from different entrepreneurs.

In this respect we would like to discuss the role of Global Village Energy Partnership (GVEP). GVEP is a unique partnership that was launched at the World Summit on Sustainable Development in 2002. GVEP is a partnership of a wide range of actors including: small and medium enterprises (SMEs) and small non profits promoting sustainable energy use in developing countries, multinational and national companies investing in renewable energy projects, community based organizations promoting the multi sectoral benefits of energy access improvements, networks of energy experts exchanging knowledge on best practices, governments, development organizations focused on building the capacity of energy entrepreneurs and many more. GVEP International helps partners from all over the world tap into the momentum generated around increasing access to energy services.

GVEP International is supported by a variety of European and US based donors. GVEP is supported by Dutch government, EDF energy, the Russian Government, the Shell Foundation, the Swedish Government, the UK government, UNDP, USAID and World Bank/ESMAP. GVEP International is increasingly working with its private sector partners such as BP, Shell Foundation, ABB, Philips, EDF Energy, Total, and Areva and with private sector organizations such as the World Energy Council (also on the GVEP Partnership Board) and the World Business Council for Sustainable Development for energy services.[56](GVEP).Thus there is a need for a large number of global partnerships.

Another important organization in India is the Confederation of Indian Industry (CII) which works to create and sustain an environment conducive to the growth of industry in India, partnering industry and government alike through advisory and consultative processes. CII is a non-government, not-for-profit, industry led and industry managed organization, playing a proactive role in India’s development process. CII catalyses change by working closely with government on policy issues, enhancing efficiency, competitiveness and expanding business opportunities for industry through a range of specialized services and global linkages. It also provides a platform for sectoral consensus building and networking. Major emphasis is laid on projecting a positive image of business, assisting industry to identify and execute corporate citizenship programmes. CII also partners with more than 120 NGOs across the country to carry forward our initiatives in integrated and inclusive development.[57]Thus upscaling at micro level to a large extent depends on collective action by a range of stakeholders and creation of intermediary actors.

[56] http://www.gvepinternational.org/
[57] http://www.sei.ashdenawards.org/partners/

### 5.4 Conclusion and summary

For successful upscaling of experiments i.e. social enterprises double loop learning in terms of development of dynamic core competencies is highly essential. Without double loop learning i.e. questioning the basic assumptions, development of heuristics, development of cognitive skills and insights required to solve complex problems successful up scaling may not happen .Further development of collective knowledge and actions from a large number of stakeholders are necessary for up scaling.

# Chapter 6: Analysis and conclusions

## 6.1 Summary of the thesis and insights from research

The first chapter discussed the motivation for research, problem definition and research objective. In the second chapter a framework for up scaling of niches as well as experiments by combining insights from system of innovation literature, strategic management, social entrepreneurship and Bottom of Pyramid literature was developed. The third chapter discussed the methodology and research process. In the fourth chapter we discussed mechanisms for upscaling of emerging PV niche in India, and in chapter five up scaling of niche experiments were discussed. This chapter summarizes main results of the research and chapter seven focuses on policy recommendations and scope for future research.

## 6.2 Answers to research questions

In this section we try to answer the research question as well as the sub questions.

**Research question: How has the PV niche developed in India and what are the different dimensions and mechanisms through which it can upscale and transform the dominant sociotechnical energy regime?**

First we try to answer the different sub questions which will lead us to the answer to the main research question.

**Sub questions**

**Methodological questions**

1. How can we synthesize insights from different streams of literature to formulate and develop scientifically grounded framework to understand up scaling of niche and experiments in PV solar energy in context of developing countries such as India?

An important question in the transition studies literature which was less understood till now was how niches start influencing regimes, and what are the mechanisms and processes which niches grow or upscale begin to influence the regime. Based on Geels (2006, pp 174-175) we built three dimensions along which niches can upscale i.e. economic, sociological and socio technical which are derived from economics, sociology of technology, social construction of technology, large technical systems and actor network theory. This framework complements the existing research about local and global niche Geels et al( 2006) ; Raven et al (2010) as well as theory of transition pathways suggested by Geels et al (2007).
For upscaling of experiments we use concepts from strategic management, social and sustainable entrepreneurship, Bottom of Pyramid and development studies literature. Thus by juxtaposing different kinds of literature and using an interdisciplinary approach of comparing multiple fields of research we try to develop a complex framework which is able to capture dynamics of upscaling at the level of niches and experiments.

2. What are the different barriers to successful up scaling of niches and experiments and the dimensions and mechanisms through which niches and experiments can upscale?

In the table below we summarize the theoretical framework used in the research with barriers, dimensions and mechanism for upscaling of both niches and experiments.

**Table 6.1**: Summary of barriers, dimensions and mechanism for upscaling of niches and experiments (Source: Own interpretation based on literature review) [58]

| Upscaling | Barriers | Dimensions | Mechanisms |
|---|---|---|---|
| **Niches** | Technological factors ; regulatory framework ; cultural and psychological factors; demand factors; production factors, Infrastructure and maintenance; undesirable societal and environmental effects; economic factors. | Economic ; sociological and sociotechnical | Pressure from landscape; internal pressure on the regime ; development of niches through expectations, social networks, learning and legitimacy; protection mechanism; stable political environment and governance and transnational linkages |
| **Experiments** | Internal issues such as lack of knowldege, human resources etc ; external issues due to regime and landscape such as unfavorable regulations, excessive support to fossil fuels, lack of political, institutional, economic, social and cultural support etc. | Quantitative; net impact; organizational;geographical;depth;functional;replication;innovation;value chain; institutional | Vision, mission and expectations ; learning in terms of development, financing and implementation of business model; human resources and partnerships and gaining legitimacy |

3. How can we link up scaling of niche (meso level) to upscaling of experiments (micro level)?

We have still not been able to develop clear linkages between upscaling of niche and upscaling of experiments from our research since this is beyond the focus of this research. However we have some suggestions in this regard. Transition studies and management studies can benefit from incorporating lessons from each other. Transition studies can benefit from incorporating main lessons about organization and management processes, cultural, social, political dynamics at micro level and up scaling at organization level while the management studies can gain insights about macro level issues occurring due to regime and landscape. The framework developed in chapter two is also capable of explaining up scaling at the experiment level (project dynamics due to management, organizational and institutional factors) as well as at the niche level (context i.e. regime and landscape factors in which experiments take place).The framework developed can be useful for explaining upscaling at both niche level as well as at the level of experiments. However one of the most important challenges is measurement of empirical indicators and evidences for understanding upscaling at both niche and experiment level without which we may not be able to gain any significant theoretical insights.

4. How suitable is the theoretical framework developed for understanding up scaling of niche and experiments in the context of developing countries such as India?

The theoretical framework developed for upscaling of niche and experiments is probably one of the first of its kind and may require several conceptual refinements before it can become usable for more empirical studies. The theoretical framework developed is quite complex in nature and makes trade off

[58] Detailed description about the barriers, dimensions and mechanisms for upscaling of niches and experiments is present in chapter two

between generality/scope, simplicity and accuracy/specificity. The framework is quite complex, highly specific i.e. suitable for understanding upscaling in the context of developing countries but not accurate. Lack of accurate empirical indicators for upscaling and methods to measure them present challenges in terms of accuracy. Therefore problems arise in the empirical operationalization of the concepts discussed in the framework. Based on this analysis we must say that the theoretical framework needs to be made simpler so that it becomes easy to use and can be operationalized with empirical data.

**Empirical question**

5. What kind of insights can be gained from the theoretical framework developed and findings obtained from analysis of upscaling of PV niche and experiments in India?

This is presented in table 6.2.

**Table 6.2**: Insights about upscaling of Indian PV niche and experiments (Source: Own interpretation)

| **Upscaling** | **Key insights** |
|---|---|
| **PV niche** | 1. Upscaling in different dimensions i.e. economic, sociological and sociotechnical is hindered by lack of industry academia linkages , lack of capabilities and knowledge to move up the PV value chain, difference in visions and expectations of various stakeholders and lack of appropriate regulatory mechanisms. Further the three dimensions are highly interrelated<br>2. Due to the National Solar Mission the Indian PV niche is being provided with high economic and political protection measures but other protection measures (institutional, socio cognitive, cultural, and geographic) have received less attention from the government. At the same time no effective monitoring (quality control, performance evaluation, learning and feedback) as well as impact assessment mechanisms have been put in place for decreasing the protection measures over time<br>3.Measures for pressure on regime have failed as high subsidies for coal and kerosene still dominate due to vested political interests and corrupt politicians, bureaucrats and people in the black market<br>4. Lack of inter ministry dialogue between the centre and state, bureaucratic nature of state electricity boards and regulatory commissions and poor infrastructure has resulted in lack of implementation of most of the legislations and laws to promote renewable energy<br>5. Indian banking sector has not been active supporter of solar energy with lack of loan portfolios for solar energy making financing difficult for users, consumers and project developers<br><br>To summarize it is quite difficult to develop general insights about upscaling of niche from the empirical data in the Indian case since the issues discussed above are very specific to India ( in terms of political situation, governance structures and institutions) and may not be easily generalizable to other countries. |
| **Experiments** | 1.There is no dominant of upscaling for experiments since different case studies show different patterns. Further it is important that experiments should upscale in all dimensions i.e. holistic upscaling, rather than upscaling in one or two dimensions.<br>2.Barriers which hinder upscaling of PV niche i.e. barriers due to power and fossil fuel regime also hinder the upscaling of experiments. Most experiments face institutional barriers and none of them have been able to modify or destabilize the existing |

| | |
|---|---|
| | institutions (regulative, normative and cognitive)<br>3.Experiments need specific protection measures for further upscaling i.e. gradual removal of economic protection so that the experiment is financially sustainable after a period of time but protection measures such as good infrastructure, stable political system, good legal and fiscal framework and corruption free environment are highly essential and experiments are unlikely to upscale if they are not provided.<br>4.There is a need for collective action from different experiments and creation of intermediate organizations to promote successful practices, standards and learning experiences gained from successful experiments for developing new experiments<br><br>To summarize these findings contrary to upscaling of niche are quite generalizable and can be applied to experiments in different contexts i.e. different countries other than India. |

**Policy question**

6. Which current and future policy mechanisms are needed in order to address dual challenges of sustainability as well as poverty reduction, job creation and economic growth through upscaling of PV niche and experiments specially in context of developing countries like India?

## Policy recommendations

The biggest challenge before Indian policy makers is high subsidies for energy regime coupled with bureaucracy, corruption and institutional failures. Powerful constituencies benefit significantly from the current subsidy regimes, and thus have a sustained interest in maintaining them. Indian policy makers are also in a dilemma whether to reduce these subsidies since unpopular decisions may provoke social unrest from the public. They need to take pro active steps in convincing the population that reduced subsidies will benefit the common man (Overland et al, 2007). However another important barrier before them is that not only do fossil fuels meet the bulk of our energy needs they also provide the feedstocks for the modern materials economy in the form of plastics, chemicals, fertilizers and so on as suggested by Meadowcroft (2007). A restructuring of fossil based regimes not only involves changes in how our energy needs are met but also changing the ways in which our other needs are met such as need for materials. This involves a lot of political decisions and there are likely to be winners and losers in the process. Therefore there is a need for reflexive learning from policy makers to understand the non linear dynamics of socio technical change which involves vested interests and political cycles. They need to take steps in reducing energy subsidies and turning them into other welfare goods by establishing trust with the common public by using various democratic measures.

Currently the policy mechanism for stimulation of renewable energy technologies are dominated by market mechanism and neo liberal ideology. For transformation of existing socio technical regime attention must be paid to policy strategies taking the multi level perspective into account i.e. by increasing the pressure on the existing regime e.g. with financial and regulatory instruments (e.g. carbon tax, emissions trading, emission norms, performance standards) along with stimulation of niches. However policies must be stable niche development trajectory needs to surpass fluctuating policy cycles so that learning experiences from the past can be used for designing new policy measures (Raven, 2005; Verbong et al, 2010). Regarding pressure on regime Indian policy makers must take active steps in two regards i.e. first increase the taxes on coal usage over the years to generate revenue for clean energy funds, second strict legal measures are needed in prohibiting black marketing of kerosene in India since even price increase measures for kerosene have not been helpful in diversion of huge subsidies of kerosene.

Alternatively the huge subsidies for kerosene can be diverted to developing renewable energy portfolios in banks for financing schemes.

The above mentioned recommendations involve long term structural changes which may take time. The current policy makers should focus on the following protection measures for stimulating and upscaling PV niches and experiments. Here we focus on some of the important measures which should be used since we cannot discuss all kinds of policy mechanisms.

**Protection measures**

**Economic**

The development of PV niche needs a banking sector which supports financing of solar energy as currently solar energy has high up front capital costs as well as high interest loans. For financing the government should look for creation of 'Solar Energy Portfolio' or green funds in banks and financial institutions whereby a certain percentage (5% at least) under the priority sector financing should be devoted exclusively for solar energy financing. The government can develop financing mechanism as it did for agriculture years ago. The channels of this financing could be the nationalized banks and regional rural banks. The percentage (5%) could be broken into two parts one dedicated financing portfolio for entrepreneurs to create a network (sales and after sales service) and another dedicated financing portfolio for end users. Apart from that the capital subsidy model for dissemination of solar energy products should be replaced by interest subsidy mechanisms with a need based solution, after sales service and appropriate financing.[59] (Srinivasan, 2009; White et al, 2009)

There is also a need for developing new means of financing for social enterprises. This can include creating conditions for appropriate capital with focus on local financing mechanisms and appropriately targeted and priced capital for enterprises from a range of investors. Some means for finance for entrepreneurs can include grant based support mechanisms, investment from patient investors, carbon financing. There is a need for patient capital for enterprises during the start up stage since carbon finance is highly risky for new enterprises.[60] The government must also pay attention to innovation funding for developing new products and services as well as capacity building for energy services. Further carbon financing potentially has a major role to play in supporting clean energy in developing countries such as India. However some barriers for carbon finance are political uncertainties, time consuming process and lack of suitability for small enterprises. There is also a need for making carbon finance simpler for small scale organizations since they are not able to avail the opportunities due to high risks and costs involved in it. (Aron et al, 2009; Prathan et al, 2010; Rogers et al, 2006).

Government should also relax value added taxes and introduce appropriately designed subsidies and tax incentive programs and establish co financing arrangements. VAT (Value added tax) has added additional burden as discussed before on the end users ranging from 4% to 12.5% in India on various solar energy products in India. Removal of taxes will straight away lead to reduction in the cost of different solar energy products. Government should also support energy and microfinance umbrella organizations for financial mechanism for poor to afford energy services (SEEP Network, 2007) [61] [62] Further there is a need for reducing duty free imports on solar energy products since Indian manufacturers prefer to import than to manufacture solar cells in India itself. (Indian Semiconductor association, 2010; Krishnan et al, 2008).

[59] http://www.financialexpress.com/news/solar-makes-sense/437497/
[60] http://www.sei.ashdenawards.org/overview/introduction/
[61] http://www.financialexpress.com/news/solar-makes-sense/437497/1
[62] http://www.sei.ashdenawards.org/overview/introduction/

Last there is a need for incentives and policies to encourage domestic electronics production in India in terms of rationalization of import and custom duty on electronic goods, tax subsidies and supportive infrastructure to facilitate local manufacturing. There is a need for collaboration with major electronic hot beds such as Taiwan, U.S., China, Japan, Singapore and European nations to attract investments in the country (Frost and Sullivan, 2010; Indian semiconductor Association, 2010).

## Institutional

India does have a tariff scheme for renewable energy (feed in tariff) for PV technology but there is a cap of 50 MW which is problematic. There is a need for a renewable energy law with legal time bound targets for renewable energy which is grid connected. The law should provide incentives for investment in RE technologies such as offering preferential tariffs, open transmission as well as incentives for buying green energy. A national trading scheme should also be supported where Indian states are encouraged to promote generation of renewable energy in excess of the state standards , for which certificate are issued and which may be tradable amongst other Indian states which fail to meet their renewable standard obligations (Greenpeace,2010).

Policy makers should also understand that policy stability is critical to creating sustained PV market growth. Policies must be in place for a long enough period of time to attract investments in manufacturing and encourage development of a mature industry. Furthermore attention must be paid to the fact that overly complex policies are not designed since they can increase project development timelines, decrease the pool of potential capital providers and ultimately increase financing and policy costs unnecessarily. Regulations must be also modified to avoid unduly applications, paper work and long waiting time for project approvals (PV SEMI group, 2009; Wustenhagen et al, 2009).

Last grid based solar energy is highly land intensive as it requires 5-10 acres required per megawatt. There is a need for an appropriately designed land use policy which will minimize land conflicts such as those seen in large infrastructure projects. This will also prevent excessive land acquisition by project developers. (Deshmukh et al, 2010).

**Socio cognitive**

There needs to be a focus on research and development through industry academia and building specialized centers for excellence for solar energy research and development and incubation centers for supporting solar energy entrepreneurs. There is also a need for government to start certification schemes, trademarks and quality certification for solar energy products since banks find it difficult to provide loans for renewable energy products as the performance of the products cannot be assured.

Based on the answers to all the sub questions we come back to the main research question

**Research question: How has the PV niche developed in India and what are the different dimensions and mechanisms through which it can upscale and transform the dominant sociotechnical energy regime?**

The answers for the entire sub questions in this chapter, analysis in chapter four and five and additional data in appendix A and B help us to answer the main research question. In addition we would like to say that one of the most important contributions from this research has been taking a holistic view of upscaling i.e. moving beyond economic measures for niches and quantitative upscaling for experiments since they have been the dominant view point of upscaling in academia as well as practice. By using the concepts from socio technical systems this research helps in providing a better perspective (i.e. looking at social, cultural, political, institutional etc issues) in understanding how far upscaling has taken place in India with respect to emerging PV niche and experiments. Since developing countries like India are rapidly growing and do not have established regimes like the developed countries there is an opportunity for stimulating niches which can transform the dominant regimes.

## 6.3 Contribution of research in academia and practice

This thesis has proved to be highly relevant both in academic as well as practical terms. In academic terms the study has resulted in up to date review of literature of transitions research, strategic management, social and sustainable entrepreneurship, development studies and integrated them in a coherent manner to understand how upscaling takes place. In terms of originality the research is a first attempt in integrating number of streams of literature which has not been done in the past since the focus has been mainly on knowledge development in specific and highly specialized professional communities without paying attention to complementary insights from other knowledge communities. This research also takes a 'Jack of multiple trades' approach as mentioned by Rene Kemp [63] which is core strength of the transitions research. Interdisciplinary research like the research presented in the thesis has the potential to develop new forms of academic practices which can destabilize existing practices. First this research has tried to answer some pending questions in transition literature such as how niches can up scale and invade the existing socio technical regimes by adapting the past theoretical frameworks into the context of developing countries. Second this research has also tried to integrate literature on strategic management, Bottom of Pyramid, social and sustainable entrepreneurship, development studies to develop insights into upscaling experiments.

For practitioners and policy makers this research offers insights into paying attention to factors other than economic mechanism which have been prevalent till now. The concept of upscaling in emerging renewable energy technologies has been focused mostly on technological and economic changes, quantitative measures conceptualized through mathematical models and assumptions without paying attention to developments in socio technical systems as discussed before. This does not mean that attention should not be paid to economic models but it must be complemented by large number of changes in the socio technical systems. The research also provides an overview of dimensions, indicators and mechanisms for upscaling niches and experiments in a more holistic manner thus influencing policy makers and practitioners to also look beyond economic measures. However at the same time this research may not offer instant solutions to practitioners and policy makers for up scaling niche and experiments and requires reflexive learning on their part to understand the complexities involved in transitions. In the next chapter we discuss methodological reflection, recommendations and scope for future work.

[63] http://www.sustainabilitytransitions.com/en/blog/2010/06/01/transition-research-has-made-a-name-but-not-yet-a-school

# Chapter 7: Methodological reflection, recommendations and scope for future work

## 7.1 Methodological reflection

The transitions research is an emerging research area i.e. 10 -15 years old and therefore still faces problems in terms of maturity of concepts. During the research we encountered several problems and would like to discuss them. Implications are discussed with respect to suitability as a research tool and application in developing countries.

### 7.1.1 Implications of transitions studies as a research tool

1. The research concepts from the transitions literature are quite new and lack maturity of an established scientific field.[64] The concepts in the transitions literature allow too much vague interpretation in terms of definition and empirical use of experiments, niches, regime, intermediate actors, global niche, transnational actors etc and other concepts. This allows researchers to suit the concepts and choice of data to suit their personal interests and biases, research objectives and research context. There has been criticisms on the transitions research by Genus et al (2008); Lovell (2007) in this regard. However lack of maturity also has a major advantage that researchers have lot of flexibility in developing the concepts according to their research focus. This flexibility is a major advantage since it allows interdisciplinary research which established scientific fields do not allow to a large extent. It also allows researchers to look at societal problems from different perspectives, cognitive beliefs and not being locked into established patterns of scientific research. For example in our case we took excessive liberty of choosing niche as an emerging sector i.e. PV sector and experiments as social enterprises/firms since there was lack of data in terms of case studies which have scaled to such an extent that we can gain insights into up scaling. However we also feel that it may not be right to take too much liberty with the concepts. Therefore there is a need for developing specific guidelines to make the concepts more operational.

2. The phenomenon of upscaling in transition studies has been discussed in multiple ways i.e. chapter two. The research is yet another interpretation of upscaling which builds upon the existing research. Since the existing research is less mature and highly flexible, our research also follows the same pattern i.e. being less mature in terms of being a starting point and subject to academic criticisms, as well as flexible i.e. allowing other researchers to use insights from the research to carry out new research.

3. Research into sustainability transitions in different geographies (different developing countries in Asia, Africa, South America) will lead to new theoretical propositions which will be dependent on national governance and political structures as discussed in table 6.2 . With respect to the Indian case i.e. the historical state controlled nature of the energy sector in setting prices and subsidizing various energy sectors and power given to state level electricity boards and regulatory commissions to implement national laws presents difficulties in terms of understanding sustainability transitions. Similar issues may arise when doing research in other developing counties. Therefore the concepts from transition studies need to be adapted accordingly.

4.The choice of empirical cases i.e. experiments in the past literature in transitions studies has been more towards pilot projects. For example Patankar et al (2010) discuss a project in Indian dairy industry in Ludhiana, India with electricity regime and a waste regime. Rehman et al (2010) discuss a project called Uttam Urja with a focus on photovoltaic lighting with an unsustainable kerosene regime in India etc. Similarly Laak et al (2007) analyze projects by Solar Oil Systems which is a firm in Boijl, the project by

[64] http://www.sustainabilitytransitions.com/en/blog/2010/06/30/transition-research-has-made-a-name-but-not-yet-a-school

the province of Friesland in Leeuwarden, and OPEK project in Zeewolde in the biofuel sector in Netherland.

The question hence arises as to why firms or social enterprises have been less discussed in transition studies. In the same country India there are large firms such as Timarpur Okhla waste management company, Jeruz energy limited, Pyromex, EDL India Ltd etc [65] which carry out several waste to energy projects and could have also been discussed. Similarly for photovoltaic lighting solutions there are several firms such as SELCO India [66], D. Light Design [67] etc in India which could have been discussed in the literature. Similarly for decentralized biomass plants firms such as Saran Renewable energy [68] or even Desi Power [69] could have been discussed. It seems that transitions researchers have been biased towards projects. This however does not mean that pilot projects should not be studied but they should be studied with respect to emerging technologies such as Nano wire solar cells, third generation fuels such as algae based biofuels where the development is likely to be development at the scale of pilot projects. An interesting suggestion will be to combine insights from small firms as well as large scale projects to gain new theoretical insights.

5. Last with respect to methodologies used, questions arise regarding the use of case studies i.e. how suitable is case study methodology for transition studies? Is it suitable because it is better suited to test elaborate processes based on changing beliefs and interests of different actors over time which can be developed through reliable primary and secondary data? According to Tight (2009) case study is essentially a convenient label which can be applied to any social science research especially when no other terms are available. A question arises: Is this also the same situation with transition studies? Tight (2009) also adds that instead of using the case study methodology researchers can discuss how the data used was created, collected and analyzed on the specific techniques involved, and their strengths and weaknesses of the process. An important suggestion therefore will be to develop new methodologies apart from case study methodology for research in transition studies.

### 7.1.2 Practical implications

1.Carrying out an inventory analysis of different experiments in large developing countries like India is a very time consuming, costly process and therefore requires careful selection of experiments which can lead to maximum learning at optimum budgets. It is better to use desktop research first and then go to field work well prepared. It is also suggested it can logistically challenging to carry out field work due to several issues such as busy schedules of people to be interviewed, large distances and several challenges which can be encountered in a developing country setting etc. A useful suggestion will be to build networks in various regions where research needs to be done and use the existing contacts and assets of the networks and contacts. This can be particularly useful in reducing high costs involved in doing research and reduce burden of funding agencies in future.

2. Another important challenge is to translate scientific based concepts from transition studies for practical purposes which can be used easily by practitioners. Transition studies have complex concepts which need to be thoroughly understood before applying them which in itself a time consuming process. Moreover the core objective of transitions research is not to offer particular solutions but instead provide a thorough understanding of the socio technical transitions by explaining technological, institutional and societal changes and inertia. However certain practitioners and policy makers may be more interested in

[65] http://www.eai.in/ref/ae/wte/wte.html
[66] http://www.selco-india.com/
[67] http://www.dlightdesign.com/home_global.php
[68] http://www.saranrenew.com/
[69] http://www.desipower.com/

concrete and readymade solutions and recommendations. Transitions research may frustrate such practitioners and policy makers. Therefore an important challenge in future will be to balance between scientific detail and practical usability and focus on finding the right practitioners and policy makers who are not just interested in readymade solutions and recommendations but in applying the concepts for policy practice.

## 7.2 Recommendations and scope for future research

From the analysis we found several issues which require further investigation for research in future. These are recommendations present interesting possibilities for follow up work on upscaling which we wanted to cover up in this research but could not carry out due to several reasons. Some of the issues are

### 7.2.1 Better theoretical models to understand transitions

From the analysis in the Indian case we found that socio technical transitions will involve politics, conflicting interests among different actors as well as power plays.This is similar to argument by (Smith et al (2010) who discuss that insufficient attention to the interests, framings, and power relations among the various actors will lead us nowhere in terms of transitions. Certain institutionally privileged actors are able to make more forceful changes to multi-level dynamics compared to many others that play a less strategic role in reproducing those dynamics. The resources needed to induce significant socio technical change are widely distributed and this makes transitions process difficult. In the Indian case we found that multiple inter linkages between actors at niche, regime, intermediate, hybrid and transnational actors makes it extremely difficult to understand which actors are central to transition process. Transitions in developing nations like India will be much more complex as sustainability issues, rural vs. urban interests and conflicts, economic growth and poverty reduction need to be solved simultaneously. This indicates that transition researchers need to come up with better models to discuss these complexities.

Transition researchers also need to focus on global and transnational actors and their role in sustainability transitions. These actors include International Energy Agency, Energy Charter treaty, G8, European Union, APEC, World Bank, World Trade Organization and APEC (Florini, 2009).These transnational organizations are highly critical for sustainability transitions since they need to resolve multiple issues such as energy security, environmental sustainability, economic development and respect for human rights simultaneously. These global actors are likely to support incumbents i.e. regime actors as well as emerging niches since they have multiple goals to meet. Hence transitions research also needs to develop adequate frameworks and empirical data to discuss the role of such transnational and global actors.

### 7.2.2 Measurement of indicators for upscaling of niches and experiments

There are still methodological challenges in measurement of indicators for upscaling of niches and experiments which were discussed before. There is a lack of qualitative as well as quantitative measures to capture upscaling of niches in different dimensions (economic, socio logical and socio technical) as well as for experiments. Upscaling is further complicated by the fact that upscaling in one dimension is related to upscaling in other dimensions making it difficult to measure the extent of upscaling.Therefore there is a need for research in future to measure focus on measurement of evidences and indicators.

### 7.2.3 Linkages between upscaling of niches (meso level) and upscaling of experiments (micro level)

As mentioned before we have still not been able to develop clear linkages between upscaling of niches and experiments. Further research is needed in this regard using insights from the conceptual framework developed in chapter two. Future research can built upon local and global niche Raven et al (2010), multi level perspective Geels (2002) and this research to develop new insights for linkages between niches and experiments.

### 7.2.4 Linkages between transition studies and economic geography: Why some regions and geographical locations have seen better development of solar energy in India than others

From our analysis we found some interesting insights. In terms of geographical coverage the Northern, Central and Western Indian markets of Uttar Pradesh, Uttaranchal, Chattisgarh, Madhya Pradesh and Rajasthan evolved largely on the back of the subsidy programs announced by the Central Ministry as well as the provincial governments wherever applicable. In contrast the market in south India especially in Karnataka and neighboring states has evolved and matured through the participation of the commercial banking sector. (Srinivasan, 2004)

South India has developed particularly well with respect to implementation of renewable energy technologies at a commercial scale. Moreover places like Hyderabad, Bangalore and Chennai in Southern India are coming up as large centers for semiconductor manufacturing for solar energy technologies as well as manufacturing of other solar energy components. We also see development of large scale solar projects in Rajasthan due to it being a hot region, Gujarat as it has large number of industrial hubs and large number of regions in Andhra Pradesh due to large availability of land. Further in India PV technology and various other solar energy technologies are also likely to be driven by state government and regional policies than national policies alone. Energy solutions will also require specific financial mechanism and there is a need for development and strengthening of regional and local financial institutions since national level policies alone may not be sufficient to solve the problems related to financing for renewable energy.

This leads us to an important insight that Indian government should focus more on building regional innovation systems in India for various solar energy technologies or develop certain regions exclusively for solar energy technologies. Cooke (2008); Cooke (2008); Cooke, (2008) discusses examples of the North Jutland region in Denmark which became hub of wind turbine manufacturing and solar thermal equipment. Similarly San Francisco area also saw VC and entrepreneurs becoming active players in clean technology sectors. Similar things were also seen in Israel. There is a possibility that due to absorptive capacity and knowledge spillovers entrepreneurs in related industries can shift from traditional sectors to high technology based clean tech sectors. Firms in geographical proximity can gain through cross fertilization to translate tacit knowledge into explicit, codified, usable and repeatable knowledge in a new business context.

In terms of social entrepreneurs deploying solar energy technologies it is possible to observe geographical clusters with high levels of social entrepreneurial activity. Specially in nations like India it might be possible to see distinct geographical factors of social entrepreneurial activity (Mair, 2006). However these issues need to be explored with the concepts of economic geography and will lead to better insights into how can clean energy technologies be deployed by development of specific regional innovation systems and how clusters of social entrepreneurs providing renewable energy services can evolve in these regional innovation systems. Such a regional focused approach could be better since national level measures in a large geographical nation like India may not work effectively. Further, the knowledge spillovers from such regions may reach other geographical regions in India.

### 7.2.5 Dilemmas and paradoxes in upscaling niches as well as experiments

Though upscaling of niches as well as experiments is necessary, attention must also be paid to moral values during the upscaling process. The way up scaling process may take place may also raise voices and questions against the fact that small scale niches and experiments may loose the core values of sustainability and instead suit interests of incumbents. Thus a lot of ethical issues, dilemmas and paradoxes may be encountered by niche actors during the up scaling process.

Smith (2007) argues that the way niches may transform into regime raises questions. He takes examples of organic food niche and supermarkets where the niche value of providing local food got diluted and similarly with giant wind turbines for off shore applications in North Western Europe which are now being developed by utilities unlike early wind pioneers. A critical challenge in up scaling niches is thus how to go mainstream without losing their valuable sustainability values while also maintaining what is valuable within prevailing regimes. There is also a need for more research on how the niche to regime transformation may take place without sacrificing the essential value of niches. If the value behind the niche is taken off and made to suit interests of incumbents and regime players then the transition may not be fulfilled. Unless the regime agrees to the value behind the niche successful scaling of niche may not happen.

At the experiment level i.e. for entrepreneurs there are several such dilemmas and paradoxes. Entrepreneurs face dilemmas about choices among which they are unable to decide as either could have unsatisfactory results. Entrepreneurs face paradoxical tensions are which are cognitively or socially constructed polarities with conflicting truths. Paradox denotes contradictory, mutually exclusive elements that exist simultaneously and for which no synthesis or choice is possible nor necessarily desirable. Entrepreneurs may have to make trade offs or a compromise and may try to build, bridge or integrate these paradoxes and make a choice which will involve a mix of both approaches. Due to the untidy, non linear, ambiguous, chaotic character of the entrepreneurial process it poses paradoxes and collisions with two opposite views. Thus entrepreneurs try to use "through-through" or "parallel" thinking for synthesizing contradicting ideas (Lewis, 2000; Lewis et al, 2000; Lewis, 2008; Lewis, 2010; Seet, 2007; Seet 2008; Tushman, 2010; Westenholz, 1999).

The factors discussed below are general dilemmas which have been developed from the literature and thus are general in nature. Specific enterprises and entrepreneurs may face specific dilemmas which cannot be discussed here. We also cannot discuss and come up with all possible dilemmas and paradoxes which enterprises may face and thus we have restricted to a few important points.

**1. Dilemmas with respect to managing tension between economic and social value creation**

Social enterprises also face tension in terms of for profit and social vision and mission (Hudson, 2009; Nicholls, 2009; Raven et al, 2010; Young , 2005).Organizational members are pulled into doing more social good by value creation or making more profit by value capture. Social enterprises thus face tensions between balancing between multiple objectives. Short term financial objectives may be detrimental to long term value creation and short term focus on social mission may erode financial viability and stun future growth (Bier, 2009).

2. **Dilemmas with respect to meeting the needs of the extremely poor**

Social entrepreneurs may also face dilemmas in terms of meeting the needs of the extremely poor with commercial approaches since their enterprises might become economically unsustainable by doing too much social good. This is because market based solutions are viable primarily in markets in which poor have at least some level of income or assets. Further, although poor people at the Base of Pyramid may be considered as having power to choose and attentive to their interests, their market based participation may also incur penalties in form of overcharging, poor quality products, products and services hazardous to their health, take it or leave it products and services. For social entrepreneurs to reach into the poorest groups some support, government grants or soft funding might be necessary which can undermine their philosophy of using commercial approaches for social purposes (George, 2009; Karmachandani et al, 2009; Martin et al, 2008).

Similarly according to Romijn et al (2009) market based solutions ignore some important issues i.e. heterogeneity among the poor, adverse power relationships, hierarchies between the poor, and intricacies of partnerships among NGO's, enterprises and poor people. Issues like profound power inequalities, diverse caste or tribal allegiances, gender biases and contradictory agendas by local parties can also undermine market based solutions. Extremely poor people may not be able to seize economic activities also due to their disconnection from national/global politico cultural and economic contexts. Influential people who act as brokers may connect development agencies to the target customers may use their elite power to take benefits, meet their private interests and make participatory projects suited more to their interests than those of the poor. Further, wider politico economic developments which are long term in nature and reflected in local contestations and struggles for survival filter into everyday lives of the poor may not be met by market based solutions.

However according to Karmachandani et al (2009) for many low income segments though not the extremely poor, reliable market based solutions can offer value and superior service at appropriate costs which the customers can judge themselves. One can never rule out exploitation of poor intended or otherwise but these risks may not be grounds for discarding potentially beneficial ventures and market based solutions. There are ways of enhancing informal market interactions and market based solutions can provide products and services with appropriate costs and better quality to build better livelihoods.Thus there are always tensions and contradictions in terms of meeting the needs of the extreme poor.

**3. Dilemmas with respect to planning the enterprise's growth or using a reflexive learning based approach**

Entrepreneurs also face dilemmas with respect to whether they should use a planned approach for up scaling or focus more on using a reflexive learning- based approach for up scaling as both have their own advantages and disadvantages.

According to Brinckman (2010); Chandler et al (2009) planning fosters the development of firms because resources are used more efficiently since decision speed is increased. It helps to predict better and prepare the organization for future since information gaps can be anticipated and closed. Written business plans can also improve performance of the firm and also encourage investors, stakeholders to take interest in the enterprise. However according to Dew et al (2009); Sarasvathy (2001) entrepreneurs can use effectual logic which focuses more on sets of means and allows goals to emerge over time from varied imagination and diverse imaginations of the entrepreneur. The idea is to focus on creating more options and look for affordable risks rather than pre- planning.

Similarly there are also dilemmas over whether entrepreneurs should use a bricolage approach i.e. create something from whatever is at hand through continuous combination, re- combination, re -deployment of different practices, organizational forms, physical resources and institutions as suggested by Mair et al (2009); Nelson et al (2005); Nelson et al (2007) or instead using a planned and a more commercial approach like a common business. Similarly according to Garud et al (2000); Garud et al (2003) an exclusive focus on outcomes can mute feedback during the entrepreneurial journey and also reduce likelihood of obtaining a favorable outcome. However according to Berchichi (2005) too much focus on micro learning processes and feedback can also be detrimental. A slow learning based approach sometimes can take a lot of time and unable to protect the innovative concept due to fast market development loops.

For example social enterprises may use a learning based approach to develop products and services for the poor but at the same time they need to make sure that too much resources are not used up with such learning based approaches. Sometimes situations can arise that either they can pay salary to their staff or use the money for learning in terms of research and development. Hence a balance needs to be maintained with respect to using planned approaches and learning based approaches.

**4. Dilemmas with respect to ethical and moral issues in running the enterprise**

During the process of running their organization social entrepreneurs may also face several ethical challenges. Some of these issues may relate to financial reporting and cost accounting in which there are possibilities of an entrepreneur engaging in unethical behavior to obtain funding when fate of the venture is in question. Sometimes some of their strategies may be manipulative and unrelenting in order to achieve their missions (Zahra et al, 2009). Furthermore entrepreneurs also tend to face ethical dilemmas involving their own values, organizational culture, employee well being, customer satisfaction and external accountability. Social entrepreneurs specially who look for social change can also profit at expense of societal or public goods and could appropriate private gains and also impose societal costs (Harris et al, 2009).

Many social enterprises may want to keep their growth restricted to a certain limit. They may not lower their standards and values for getting more customers as they might be strongly committed to sustainability and social mission. Some of them may also decide not to upscale and reach a size to attract undue interest from incumbent players. Thus they might prefer to keep their ventures small and exclusive. However some of the enterprises may be more professionals and backed up by professional investors and would like to expand and scale quite fast (Hockerts et al, 2009).

Similarly according to Zahra et al (2009) there could be also a considerable difference in how far the enterprises may want to scale. They make an attempt to classify social entrepreneurs into social bricoleur, social constructionist, and social engineer depending upon their problem solving capabilities and meeting local needs, ability to acquire resources for their mission and ability to bring institutional changes and reforms. According to them social engineers like the Grameen Bank were able to modify some existing institutions as it had large visions but on the other hand there are some entrepreneur's like social bricoleur who want to restrict to local solutions and may not look for upscaling too much. Therefore social entrepreneurs might be confronted with several ethical and moral issues in terms of upscaling.

It is thus regarded that an investigation into dilemmas and paradoxes can lead to better insights into the phenomenon of up scaling.

## 7.3 Conclusion

We feel that more insights about upscaling of niche and experiments can be provided by working further on possibilities for future research which were just discussed. It is also stressed that heuristic concepts of systems of innovation and system level transitions while help us in making the problems of sustainability more structured and bringing out the core issues, they also need to be complemented with other kinds of relevant concepts and insights as well.

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# Appendix A: Up scaling of the Indian PV niche

### 9.1 Landscape factors

There were several landscape factors which contributed to development of the Indian PV niche such as energy security, sky rocketing conventional energy prices and chronic shortages of electricity, fluctuations in oil prices, liberalization of economy, liberalization of energy markets, public awareness of climate change, government commitments to meet national and international targets for emissions reductions. Most important PV technology in India also received importance due to other issues such as energy poverty since a large section of India lacks access to energy services.

### 9.2 Overview of development of PV niche in India

The development of niche is discussed in different phases

1.Initial phase: Initiation and demonstration programmes (1980-1990)

2.Development of niche market: Commercialization phase (1990–2000)

3.Development of PV value chain activities in India (2000- Present)

4.Future developments with respect to National solar mission

In addition we also discuss development of global niche through intermediate actors, global linkages and knowledge flows responsible in development of the Indian PV niche so far and various protection mechanisms provided by government to support the emerging PV niche.

#### 9.2.1 Initial phase: Initiation and demonstration programmes (1980's- 1990's)

The programme for development of photovoltaic technology and its applications in India was initiated as far back as 1976. A major programme for development, demonstration and utilization of PV systems was started in the 1980s. In 1980's a five year programme for bringing the technology to a stage of commercial production was taken up. The programme also included development and demonstrations of various PV applications. During the time period 1985 -1992 a major programme for the development of single junction amorphous silicon solar cell technology was implemented (Bhargava, 2001).

In 1981 CASE (Commission for Additional Sources for Energy) under Department of Science and Technology, Ministry for Human development, Government of India was established to promote renewable energy technologies in India. Later on in 1982 DNES (Department of Non Conventional Energy Sources) was created in 1982 under the Ministry of Power which was upgraded to Ministry of Non Conventional Energy sources in 1992. MNES was changed into MNRE (Ministry of New and Renewable Energy) in 2006. During 1980's research and development of renewable energy technologies was carried out through financial support and subsidy from the government. There were several technology specific programmes which included capital grants, interest grants, tax incentives and duty exemption.

Later on capital subsidies were discontinued to promote commercial viability of renewable energy technologies. In 1987 IREDA( Indian Renewable Energy Development Agency ) was formed which is a public sector enterprise to finance renewable energy projects and was world's first financial intermediatery solely dedicated to financing of renewable energy initiatives. IREDA also provided financial support to manufacturers and users and assisted in rapid commercialization of renewable energy technologies. It also offered soft loans to prospective developers with loans from World Bank, other bilateral and multi lateral institutions like GEF and Swiss Development Corporation(SDC), International

Finance Corporation (IFC) and PVMTI (Photovoltaic Market Transformation Initiative) initiated by World Bank. Since its inception IREDA has been functioning and operating a revolving fund to develop, promote and finance commercially viable energy efficient and renewable energy technologies in India. Over the years IREDA has provided small loans and business development skills to Indian entrepreneurs and specifically for the creation of appropriate marketing and financing mechanisms ideally suited to the unique requirements of renewable energy technologies. IREDA also helped bearing huge financial risks associated with investment in renewable energy technologies. MNES also established Solar Energy Center for carrying out research, development, testing and certification of solar energy products. It also established a wide range of research, development and demonstration activities, elaborate incentive schemes and state level nodal agencies for promoting renewable energy technologies in the country. (APCTT- UNESCAP, 2009; Bhattacharya, 2009; Chaurey, 2001).

During this period MNES was involved in demonstration projects, awareness creation, technology development and provision of budgetary support to various initiatives. The Ministry functioned through various state level nodal agencies which it has helped set up to implement the given mandate and help disseminate information, technology, finances and know how. However IREDA was also found to be excessively bureaucratic in nature leading to several problems. In addition financial Intermediaries like IREDA often exploited the project developers by resorting to financial engineering to create a single up front lease payment for PV systems and not providing longer term low cost credit to the end customers. Thus government agencies such as IREDA did not focus on long term sustainable business organizations and instead focused on short term gains thus defeating the purpose of seed capital (Srinivasan, 2005).

The 1980’s also saw development of Indian photovoltaic industry in form of producers and manufacturers as a result of application oriented programmes which were sponsored by Indian government. Such demonstration projects provided a platform for the technology without facing great technological or commercial risks. During the time period 1980-1985 several programmes took place sponsored through a public sector electro Technology Company called Central Electrotechnological Company (CEL) and initiated by Department of Non Conventional Energy (DNES). The second company in the Indian PV sector was a public sector company called BHEL (Bharat Heavy Electricals Limited) which was in the business of power equipment. The company held its monopoly until 1990’s after which some firms came into the market namely contribution Renewable energy enterprise (RES),a private sector company and another stated owned enterprise called REIL (Rajasthan Electronics and Instruments Limited).However the major milestone in this period in the Indian PV sector was the joint venture between BP Solar UK and TATA which lead to the formation of TATA BP Solar which started production of PV modules in 1991-1992.It is among the largest manufacture of PV modules today in India. Later on M/s renewable energy systems Hyderabad also came into the market which was one of the first private sector companies in solar photovoltaic systems manufacturing in India (APCTT- UNESCAP, 2009; Chaurey, 2001).

The period also saw development of several research programmes with respect to Photovoltaic technology which were focused on fabricating solar cells and designing simple applications. In 1980’s national solar photovoltaic development programmes took place from 1980-1985. In 1981 a five year programme was started by the government for bringing PV technology to a stage of commercial production. The programme also included the development and demonstration of a variety of applications. This phase was followed by a period of further development of different solar cell technologies .Indigenous solar cell was developed by Central electronics limited.IISc carried out research on development of polysilicon material. A mission project also took place between IACS, IIT Delhi, NPL, IITM, IITKGP, CEL, REIL for development of amorphous solar cell. IIT Delhi and Indian Association for Cultivation of Science were also involved in development of amorphous silicon solar cells. Cochin University and Rajasthan University were also involved in thin film techniques and IISC Bangalore in development of CIGS cells. BHEL also collaborated by NSW Australia for development of

PV technology. Independent testing of PV systems took place at IIT Delhi and solar energy center (Banerjee, 2009).

During the period PV systems were found to be commercially viable for several applications such as portable lighting units, water pumping, small power plants, telemetry on off shore oil platforms, railway signaling, low power transmitters, microwave repeaters. A major expansion of the telecommunications network initiated in the late 1980's and early 1990's in India created a need for reliable small power systems for rural radio telephones and established a major market for the PV industry. The market for Telecommunications was independent of government subsidies and thrived on its merits for providing electricity to unstaffed locations. Other major PV applications in that period were roof top systems on public buildings and tail end voltage support for rural grids. (Bhargava, 2001; Chaurey, 2001; Sastry, 1997).

### 9.2.2 Development of niche market: Commercialization phase (1990's – 2000)

During this period a programme for the development and deployment of PV systems was included in the Eighth national five year economic plan which began in April 1992. Later on in June 1993 a new strategy and action plan was started for accelerating the utilization of renewable energy technologies was drawn up by MNES. Among the initiatives taken were a new programme on water pumping systems, increased deployment of solar lighting systems, commercialization of PV products and market development through special incentives (Sastry, 1997). IREDA also launched its Solar PV development programme in 1993-94 in order to promote commercialization of the technology based on experience gained since the initiation of India's national solar PV programme earlier (Bhattacharya, 2009).

The design and development of solar lanterns in India was initiated in 1991 under the national programme on SPV demonstration. The dissemination of solar lanterns however faced challenges related to operational, financial and marketing aspects. Lack of awareness among prospective users, limited outlets for procurement, unavailability of different models catering to varying needs among various user segments, high price and limited hours of usage were some of the reasons cited for poor dissemination of solar lanterns in the country during the 1990's **(**Chaurey et al, 2009).

From 1993 onwards IREDA started projects to develop renewable energy technologies and make the transition from supply driven approach to a demand driven approach in which consumers would have a choice of products and services. The projects made slow progress due to difficulties in reaching dispersed rural population, high transaction costs, inadequate support infrastructure and lack of entrepreneurs. MNES also started Akshay Urja shops to provide sales and services to renewable energy users. Later on the scheme was extended to private entrepreneurs to avail low interest loans to establish shops. Such schemes were successful in creating sales and service networks in remote areas and training local youth as entrepreneurs. NGO's such as Barefoot Engineers, GERES, PEN also played an important role in developing PV sector in India .This also led to some projects in future like Shri Shakti Renewable Energy Technology project which supported 300 energy stores throughout the country to sell PV based consumer projects and provision of consumer finance for sale of solar home systems in West Bengal. The Shell Renewable energy project focused on development of a marketing, retail, service network and provision of consumer finance for sale of SHS in rural areas in Southern India (APCTT- UNESCAP, 2009).

During the time period several research centers were also established. The Solar Energy Center conducted research on solar energy in collaboration with institutions like IIT Bombay, IIT Delhi, TERI New Delhi, IARI New Delhi, NPL New Delhi, Department of Scientific and Industrial research, Council of Scientific and Industrial Research. A PV test facility was set up at the Solar Energy Centre (SEC), Gwal Pahari near Delhi to qualify PV modules to the recent IEC and Indian standards as well as testing of the BOS (Balance of systems) and complete PV systems to ensure product quality. Testing facilities were also set up at Bangalore, Calcutta and Trivandrum by the government for regular testing of solar lanterns and other lighting systems. Several other institutes such as National Physical Laboratory, National Aerospace Research Bangalore, Indian Academy of Sciences Kolkatta, Gadoid Solar Energy Technologies did research on various solar energy technologies. Later on National Innovation Foundation was started in 2000 for providing institutional support in finding sustaining and scaling grass root green innovations through the Honey Bee network and SRISTI (Society for Research on and Initiatives for Sustainable Technologies and Institutions) (Chaurey, 2001).

However manufacturers during this time period also faced losses with sales to government organizations and began to export PV modules to make use of their excess production capacities. Export and rural electrification provided commercial alternatives for Indian PV industry till that time period (Ockwell et al, 2009). Thus the Indian solar PV industry was driven mainly by the activities of government, nongovernmental organizations (NGOs) and international organizations .Most firms were state run, joint sector and private companies. The private sector consisted of firms with complete Indian ownership, joint ventures with multinationals and foreign owned subsidiaries (Ockwell et al, 2009).

### 9.2.3 Development of PV value chain activities in India and entry of private players (2000-Present)

From 2000 onwards India also saw development of economic activities across the global PV value chain. This was important as this led to development of new sectors and subsectors with backward and forward linkages. However before explaining the activities in the Indian PV value chain we would like to discuss the global PV value chain in order to show the actual position of India globally.

**Global PV value chain**

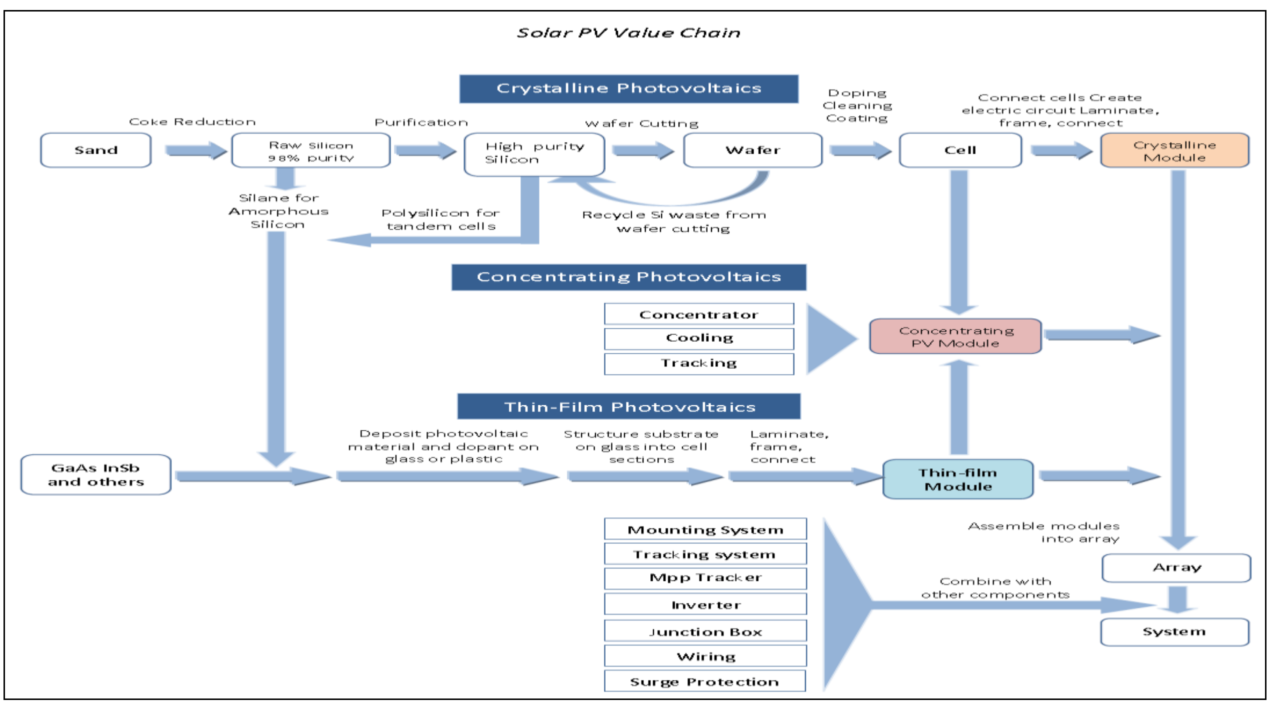


**Figure 9.1:** Global PV value chain (Source: EAI India solar PV report, 2010)

The PV value chain can be separated into five main components which depend on each other: silicon feedstock production, ingot casting and wafer slicing, cell and module production, system integration and sales. Feeding into module production as well as system integration are the value chains for other components. These are usually referred to as balance of system (BOS) comprising structures, enclosures, wiring, switchgear, fuses, ground fault detectors, charge controllers, invertors and batteries which are needed for PV modules to work (Ockwell et al, 2009).

The upper part of the value chain i.e. polysilicon manufacturing is dominated by large semiconductor manufacturers such as Hemlock, Tokyuma, Wacker Chemie, REC and MEMC and has an oligopolistic market with top 5 firms controlling more than 85 % of the market. Polysilicon manufacturing is dominated by firms such as Shinetsu, SUMCO Wacker, MEMC, and Komatsu in which the top 10 firms control more than 70 % of the market. The solar cell manufacturing part is currently dominated by nations such as Japan, US, Europe, China with firms such as Sharp, Sanyo, Kyocera, First Solar, Sun power, Q cells, REC solar, SunTech, Solar fun, Motech .Some other firms such as Opti solar and Evergreen solar are using other technologies for reducing amount of silicon. Furthermore most of the top solar PV companies are located in Japan, Germany, China, USA, UK and Taiwan.[70] The lower part of the PV value chain is highly distributed with large number of players across the world (Indian Semiconductor Association, 2008; Sanyal, 2008).

Another major issue with the upper part of the PV value chain is the supply of silicon to the wafer based industry. The availability of silicon feedstock over the years has been acknowledged as a critical issue in keeping up the high industry growth rates up to the levels of the present time. As a consequence the PV industry depends more on the needs of the semiconductor industry. Over the years the price of silicon increased from US$25 per kilogram in 2003, to US$250 and some spot prices for PV grade silicon reached US$300 – 450 / kg in 2008 (Ockwell et al, 2009 ; Sark et al, 2007). Thus the silicon market has been highly fluctuating in the past leading to imbalance in demand supply equation, fluctuating prices and availability of raw material [71] (Indian Semiconductor association, 2010).

**Indian PV value chain**

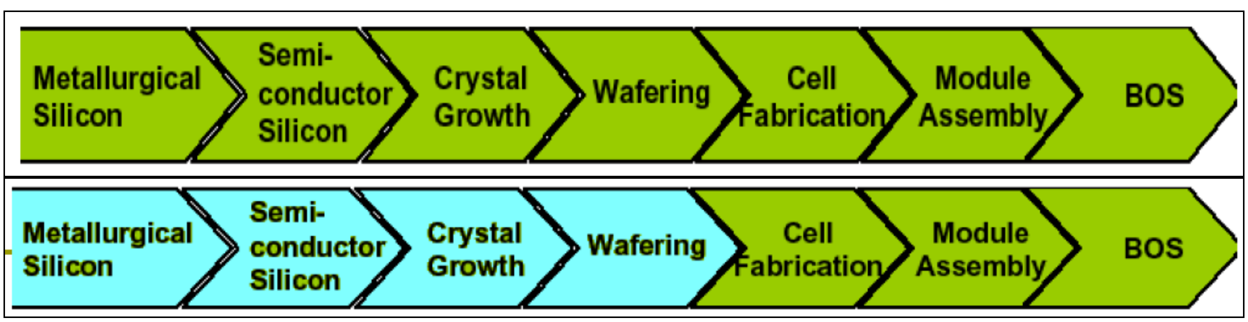


**Figure 9.2:** Position of India in global PV value chain (Source: Subramanya, 2010)

As shown in the figure above the upper parts of the PV value chain in blue i.e. (metallurgical silicon, Semi conductor silicon, crystal growth, wafering) are not carried out in India. With respect to the lower

[70] http://www.slideshare.net/sanjoysanyal/introductionto-solar-presentation-812649

[71]http://www.indiainfoline.com/Markets/Company/Fundamentals/Management-Discussions/Moser-Baer-India-Ltd/517140

parts of the value chain India has several actors in each part of the value chain with number of actors increasing in the lower parts of the value chain.

There are about 15 players in cell manufacturing, over 20 players in modules and more than 60 in solar assembly. The Indian PV module manufacturing industry comprises cell and module manufacturers who import silicon wafers and process them into cells and modules. All commercial PV module manufacture in the country is based on crystalline silicon cells while substantial research and development effort continues to go into thin film technologies i.e. a-Si, CIS, CdTe modules. The industry is divided into government corporations such as Central Electronics Limited (CEL), Bharat Heavy Electricals Limited (BHEL) and Bharat Electronics Limited (BEL) and other private or joint sector manufacturers such as Tata-BP, Webel- SL, USL Photovoltaics, Microsol Power, Maharishi Solar etc.

Currently there are several manufacturers namely TATA BP solar, Solar Semiconductor, photon energy systems, CEL, Reliance industries limited, Moser Baer, Maharishi solar, BHEL, Webel, REIL, Titan energy systems, Signet solar, Velankani renewable, Lanco infratech, Sharp, KSK energy ventures, Indo solar, Central Electronics Limited (CEL), KSK Energy, High HindVac (HHV), Environ, Sem India Systems, Bharat Heavy Electricals Limited (BHEL), Lanco solar (Banerjee et al, 2009; Indian Semiconductor association,2010; Ockwell et al, 2009; PV SEMI Group, 2008).

Furthermore nearly 90% of the solar modules manufactured in India, use crystalline silicon C-Si technology, while only 10% of the solar modules are manufactured using thin film or amorphous silicon technology. This is also shown in the table below.

**Table 9.1:** Status of various photovoltaic technologies in India (Source: Indian Semiconductor association, 2010)

| Technologies | Extent of commercialization | Market share | Stabilized efficiency | Raw material requirement | Long term stability (modules' warranty) | Remarks |
|---|---|---|---|---|---|---|
| C-Si (mono & multi) | Fully commercialized | Approx. 90% for the last few years | 13-18% at commercial scale | 10-12 gms silicon / Wp for thickness of 250 microns | 20-25 years | Better power per unit area |
| Thin Film (a - Si) | Not as commercialized as C-Si | Approx. 10% for the last few years | 6-9% | 0.7-0.9 gms silicon / Wp | 20-25 years | Relatively less power per unit area |
| New Emerging (Organic) | At R&D or pilot study stage | | 4-6% | Regular commercial production not stabilized | Yet to be established | Uses relatively cost effective material |

In India mature technology for silicon cells is available on the market without patents since most of the patents have expired. Most firms in India have been focusing on silicon technology as it is well known and raw material has been available easily. However many firms have also been locked into silicon based PV technology because of the amount of infrastructure, equipment and personnel investments already made in the area. Over the years Indian PV industry has also developed a reputation to produce good quality products at significant lower costs due to some factors such as good engineers and technicians with significant lower salaries. At the same time Indian firms have been undertaking numerous strategies to acquire technology including in house R&D, licensing, and partnerships and acquisition (Bharagava, 2001; Ockwell et al, 2009; White et al, 2009). The capacity in India is currently estimated in excess of about 400 MW2\ for cells and about 1000 MW for PV modules. The production data for solar cells and PV modules over the years is shown below in the figure.

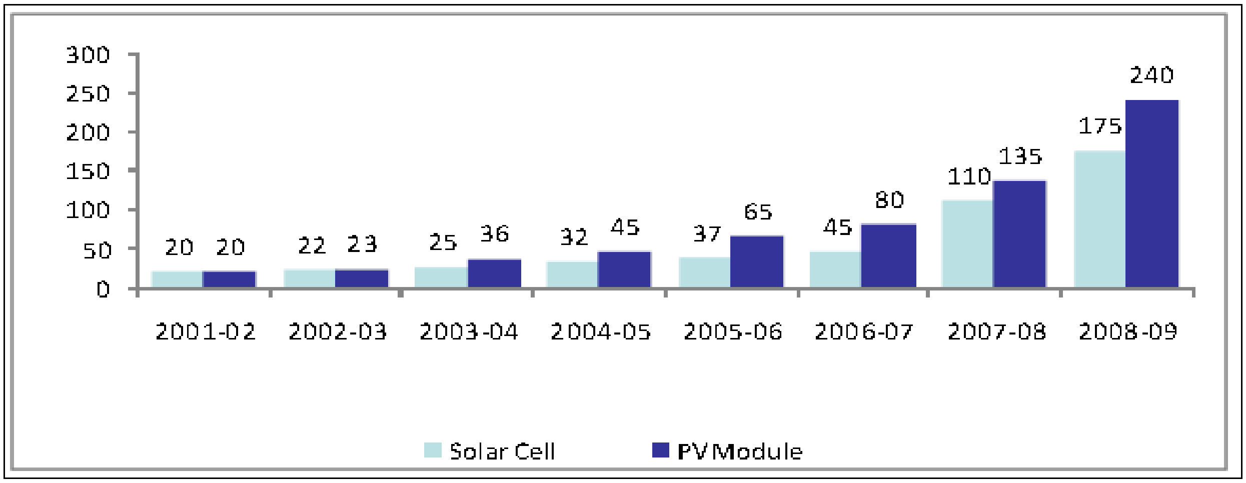


**Figure 9.3:** Trends in production of Solar PV cells and module in India (Source: Indian Semiconductor Association, 2010)

**Indian PV market with respect to export and domestic market**

The Indian module industry has been divided attention between export and domestic markets. The module industry has been successful in selling about 70 % of its total production abroad providing international competitiveness. Most Indian module manufacturing operations in India have been labor intensive and operating at competitive costs of production when compared to more automated plants in western nations. Indian module makers have also obtained international certification for their operations to enhance their image in highly competitive markets abroad. India has become a high quality, low cost manufacturing base for smaller modules made from imported wafer and cells (Srinivasan, 2004; Srinivasan, 2007).

During 2008-09, about 80% of the total solar PV imports were from Germany and Taiwan. The other countries for solar PV imports were Spain, China & Japan. On the other hand Germany and Spain were also the major export markets for Indian solar PV producers. The figure below also shows the exports of Indian PV industry

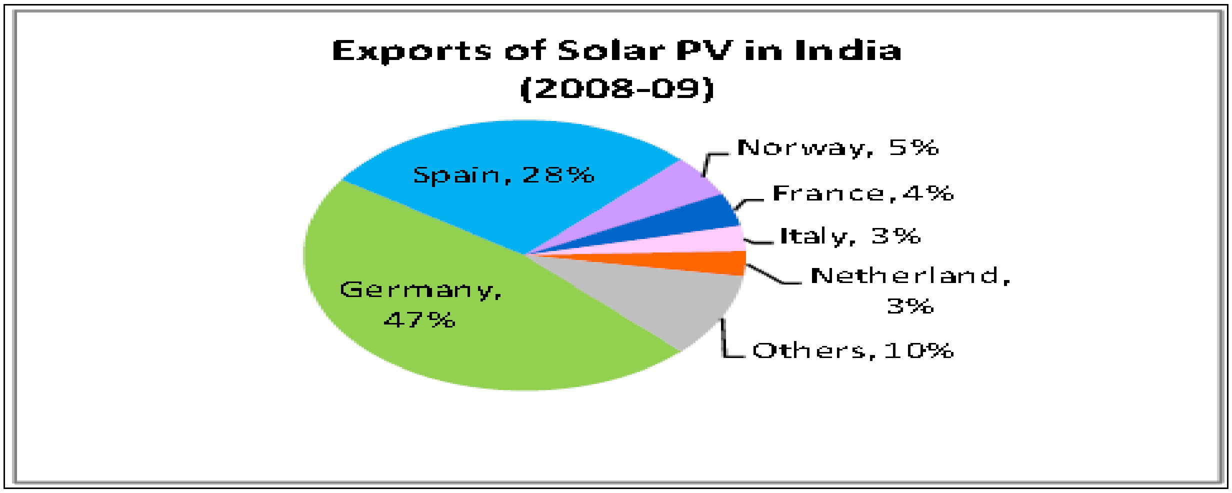


**Figure 9.4:** Export of solar PV from India (Source: Indian semiconductor association, 2010)

During 2008-2009, Germany and Spain accounted for about 82% of the total exports from India. Other export markets included Netherlands, Italy, Belgium and Afghanistan. On the other hand on a cumulative basis domestic market sales accounted for less than 35% of overall sales of the manufacturers in India. The solar PV market in India has been highly under developed with applications limited mainly to railways, telecom industry and defense. Some of the key reasons for the slow development of the domestic market have been low commercialization levels of PV based generation, low awareness across end users and lack of regulatory support (Indian Semi conductor Association, 2010). Although the Indian PV industry has done well in terms of becoming a low cost and quality manufacturing hub for western nations but not much has been done with respect to moving up the PV value chain. There has been no manufacturing base in India for the basic raw material i.e. silicon wafers. The industry has relied on international markets to source the raw material. In addition the major international players with huge capacities and already depreciated plants, with access to advanced technologies and continuous R&D, are in an advantageous position to steer global polysilicon markets compared to many of the new entrants. India is also planning to establish a polysilicon plant which can supply cell manufacturing needs of 2000 MW per year by 2020. The fact that Indian manufacturers depend almost entirely on import of silicon wafers or strips to make PV cells is a key driver for encouraging investments in the silicon supply chain and especially polysilicon production. A few companies including Moser Baer and Environ have indicated plans to produce the entire PV value chain. An increasing number of companies have been involved with or exploring thin film solar technology including Titan, Signet Solar, Moser Baer PV Ltd., KSK Surya Energy, and Hind High Vac (HHV) [72] (Bharagava, 2001; Ockwell et al, 2009; White et al, 2009).

In the lower stage of the PV value chain i.e. balance of systems the Indian PV industry in India consists of over 60 balances of systems manufacturers and system integrators who produce charge controllers, inverters and battery systems. It is considered that innovation and improvement in quality, reliability and efficiencies in the balance of systems stage is important for delivering better overall system performance and important determinant of wider PV adoption. India has for many years had a thriving industry producing uninterruptible power supplies consisting of charge controllers, battery back-ups and inverters. PV system integrators in India offer end to end solutions based on third party PV modules including

[72] http://www.pvgroup.org/NewsArchive/ctr_036225

imports. Some of PV manufacturers are also emerging as key players in the balance of systems stage. Many companies in the upper parts of the value chain including major manufacturers of cells and modules have also integrated down the supply chain and offering end to end PV solutions, including grid connect subsystems **(**Banerjee, 2009; PV SEMI Group, 2008).

Some of the well known system integrators have been SELCO India, Shell Solar India, TATA BP dealerships, Environ Energy Tech Systems (Calcutta) and NGOs and social organizations such as the Ramakrishna Mission (RKM) and the Social Work Research Center (SWRC). These integrators are typically, local or regional players and benefit from an in depth knowledge of the socio economic political realities in their geographies and have also enjoyed a good rapport with their customer base and with financial intermediaries. These service providers typically source entire systems or components of systems from established manufactures. These service providers also act as the domestic distribution arms of the module and component manufacturers and also provided grass root level customer interface and periodic service. These system integrators have also focused on post installation services which also have been source of revenue. In future it is also expected that the market is likely to grow on the back of these system integrators with partnerships with rural and co operative programmes (Srinivasan, 2007).

**Large scale PV projects in India**

Many public sector enterprises such as National Thermal Power Corporation and Bharat Heavy Electricals limited, Oil and Natural Gas Corporation are also coming up with gird connected solar energy plants. The private sector has also come up power plants. Azure Solar ltd came up with the first 2 MW solar plant in India.[73] Titan Energy has just completed the construction of a 1 MW unit for the West Bengal Green Energy Development Corporation. State governments are also coming up with Andhra Pradesh government setting aside 6000 acres in Anantapur district for allotment to companies setting up solar power projects. In Gujarat the government is talking to the Clinton Foundation in partnership with TERI is assisting government of Gujarat for development of solar parks with capacity of more than 3000 MW.

In February 2009 MNRE (Ministry of New and Renewable Energy) announced a scheme on Development of Solar Cities to promote the usage of renewable Energy in urban areas by providing support to Municipal Corporations for the preparation and implementation of a road map to develop their cities as Solar Cities. An indicative target of 60 cities/towns with at least one in each State has been set up. In a major development under this scheme the Government of Andhra Pradesh has recently announced the development of a solar farm cluster called Solar City on a 10000 acre land at Kadiri in Anantapur district. Four firms Sunborne, Lanco Solar, AES Solar and Titan Energy have signed memorandum of understanding with the state to set up establishment in Solar City. [74]

**Research and development**

In terms of research and development the government of India also proposed activities to increase solar cell efficiency to 15 % at commercial level, improve modules to have higher packing density and increase suitability for solar roofs for usage in solar lanterns. Some institutions such as IIT Delhi have achieved good efficiencies in non silicon based technologies. However the problem has been that Majority of PV industry players have been not involved in the research process with the universities. There has been a problem of linkages between them and lack of know how about deployment of new PV technologies on a commercial scale. Out of the many research centers in India on solar energy technologies only 12 have been research active. Indian firms are also collaborating with universities in USA and China instead of

[73] http://www.solardaily.com/reports/Indias_first_commercial_solar_power_plant_999.html
[74] http://knowledge.wharton.upenn.edu/india/article.cfm?articleid=4437

Indian universities due to lack of knowhow for commercialization of technologies among the Universities (Ockwell et al, 2009; White et al, 2009).

### 9.2.4 Future developments with respect to National Solar Mission

The National Solar Mission program was initiated by the Government as one of the 8 programs under the National Action Plan for Climate Change by the Prime Minister of India in 2008. In the month of November 2009, the Mission document was released as Jawaharlal Nehru National Solar Mission (JNNSM) and the Mission was formally launched by the Prime Minister on January 11 2010. The mission thus has kept two important targets in mind i.e. first to scale up deployment of solar energy keeping in mind the financial constraints and affordability challenge in a country where large number of people still have no access to basic power and are unable to pay for high cost solutions. The immediate aim of the mission is to focus on setting up an enabling environment for solar technology penetration in the country both at a centralized and decentralized level. The mission will be implemented by an autonomous solar energy authority embedded within existing structure of the Ministry of new and renewable energy .The Mission will report to the Prime Minister's Council on Climate Change on the status of its programme.
It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. The Mission anticipates achieving grid parity by 2022 and parity with coal-based thermal power by 2030, but recognizes that this cost trajectory will depend upon the scale of global deployment and technology development and transfer. The mission will adopt a three phase plan i.e. from 2012-2013, from 2013-2017 and from 2017- 2022. The first phase up to 2013 will focus on solar thermal; on promoting off-grid systems to serve populations without access to commercial energy and modest capacity addition in grid based systems. In the second phase after taking into account the experience of the initial years, capacity will be aggressively ramped up to create conditions for up scaled and competitive solar energy penetration in the country. The Mission will work closely with State Governments, Regulators, Power utilities and Local Self Government be can be implemented effectively. (Jawaharlal Nehru National Solar Mission: towards building SOLAR INDIA)

### Grid based applications

India has put a mechanism of feed in tariff under the national solar mission intended to deliver 20 gigawatts (GW) of installed capacity by 2022. NTPC Vidyut Vyapar Nigam (NVVN) Ltd. has been designated as the nodal agency for entering into a Power Purchase Agreement (PPA) with solar power developers which are valid for 25 years. The PPAs shall be signed with the developers who will set up solar projects connected to the grid at 33 KV level and above. For each MW of solar power installed capacity for which PPA is signed by NVVN, the ministry of power shall allocate to NVVN/ the state utility an equivalent amount of MW capacity from the unallocated quota of NTPC stations. NTPC will buy solar generated electricity at a fixed rate determined by the Central Electricity Regulatory Commission (CERC) each year per kilowatt hour (one unit) of solar electricity with respect to norms set by MNRE.In order to make solar generated electricity more affordable NTPC will bundle four units of thermal power with each unit of solar power dragging the cost of electricity down to around INR 4.5 per unit. Energy utilities will then be required to buy the solar power bundles as part of India's wider renewables purchase obliation (RPO) being implemented. The bundling of more expensive solar power with cheaper thermal power will enable a much cheaper tariff which is estimated at around INR 5 or less per unit. India is also counting on rich nations to pick up most of the USD 19 billion tab estimated for the entire programme which encompasses three phases and ends in 2022 [75](Indian Semiconductor Association, 2010)

[75] http://www.rechargenews.com/energy/solar/article203215.ece

**Off grid and decentralized PV applications**

The national solar mission is also focusing on off grid and decentralized applications where grid penetration is neither feasible nor cost effective. The Government has promoted the use of decentralized applications through financial incentives and promotional schemes. The Mission plans to provide solar lighting systems under the ongoing remote village electrification programmers of MNRE to cover about 10000 villages and hamlets. The use of solar lights for lighting purposes would be promoted in settlements without access to grid electricity and since most of these settlements are remote tribal settlements. For this purpose 90% subsidy will also be provided. In order to create a sustained interest within the banking community the mission has also proposed to provide a soft re-finance facility through Indian Renewable Energy Development Agency (IREDA) for which Government will provide budgetary support.

IREDA would in turn provide refinance to NBFC ( National Banking Finance Corporation) and banks with the condition that it is on lend to the consumer at rates of interest not more than 5 per cent. The Mission would provide an annual tranche for the purpose which would be used for refinance operations for a period of ten years at the end of which the funds shall stand transferred to IREDA as capital and revenue grants for on lending to future renewable energy projects. The national solar mission will also support incubation and start ups by tie up with institutions like Center for Incubation and Entrepreneurship (CIIE) based in IIM Ahmedabad to incubate solar energy start ups and SMEs in India through mentoring, networking and financial support. A fund will support at least 50 start ups in solar energy technologies.

**Research and development and large scale manufacturing**

A National Centre of Excellence (NCE) shall be established to implement the technology development plan formulated by the Research Council and serve as its Secretariat. It will coordinate the work of various R&D centers, validate research outcomes and serve as an apex centre for testing and certification and for developing standards and specifications for the solar industry. The mission is also developing an ambitious human resource development programme, across the skill chain to support the expanding and large scale solar energy programme .Further the national solar mission is also focusing on research and development to focus on improving efficiencies in existing materials, devices and applications on reducing costs of balance of systems, establishing new applications by addressing issues related to integration and optimization, developing cost effective storage technologies which would address both variability and storage constraints in off grid solar solutions.  A Solar Research Council will be set up to oversee the strategy taking into account ongoing projects, availability of research capabilities and resources and possibilities of international collaboration. The government is also setting up of a National Centre for Photovoltaic Research and Education at IIT, Mumbai drawing upon its Department of Energy Science and Engineering and its Centre for Excellence in nano electronics.

The national solar mission is also looking on reducing Indian solar PV industry's dependence on imports of critical materials and components including silicon wafers. The government is also providing proactive implementation of Special Incentive Package policy to promote PV manufacturing plants, including domestic manufacture of silicon material. The small sector manufacturing for solar energy systems will be supported through soft loans for expansion of facilities, technology up gradation and working capital through support from IREDA.The government has also announced zero import duty on capital equipment, raw materials and excise duty exemption, low interest rate loans, priority sector lending and planning to create 2-3 large solar manufacturing tech parks consisting of solar manufacturing units across the value chain.

**Global linkages**

The mission is also dependent on international collaboration and looking for bilateral and multilateral arrangements. Strategic international collaborations and partnerships are also aimed at meeting the priorities set out under the Mission would be developed along with effective technology transfer mechanisms and strong IPR protection. The Department of Science and Technology has been supporting joint research with several countries under bilateral programmes. More recently a research programme has to be taken up by DST, in consultation with MNRE and with the European Union. MNRE is also implementing some bilateral projects under the Asia Pacific Partnership Programme with Japan and Australia and several programmers with U.S.A.The mission is also relying on international funds from UNFCCC(United Nations Framework Convention on Climate Change ) of framework to meet its targets. (Jawaharlal Nehru National Solar Mission; Towards building SOLAR INDIA)

**9.3 Development of intermediary organizations**

At the global level large number of intermediate associations have been developed in the field of solar energy. Some of the renowned intermediate associations for solar energy are International Solar Energy Society (ISES), World Energy Council, World Council for Renewable Energy, American Solar Energy Society (ASES), Clean Edge, Greenpeace, Solarbuzz, Solar Electric Power Association, Solar Energy Industries Association, European Photovoltaic Industry Association, Eurosolar, British Photovoltaic Association, Indian Development Association, International Solar Energy Society, European Photovoltaic Industries Association ,the Solar Alliance (2009) and many other organizations (Promethus Institute , 2005).

However there has been lack of intermediate organizations for development of solar energy in India. Some of the associations in India are The Indian Semiconductor Association (ISA) under their PV section; SolarIndiaOnline,a small group of people active in disseminating information about PV technology; Renewable energy action forum(REAF), a Bangalore based group with people from diverse backgrounds from academia, industry are some of such intermediate associations in India. Most of these groups are quite new and the oldest among them is since 2004 only (Ockwell et al, 2009).

India has also few trade associations such as Semi Conductor Equipment and Materials International (SEMI) for collaborating with Indian semiconductor association to increase public knowledge on solar energy technologies, Solar energy society of India (White et al,2009). The Federation of Indian Chamber of Commerce Industry (FICCI) also has a task force on solar energy with representatives from the solar energy. The task force comprised manufacturers of photovoltaic cells and modules, systems integrators and power project developers with some important people like The Union Minister for New and Renewable Energy, the Union Minister for Power, the Deputy Chairman of the Planning Commission, the Principal Secretary to the Prime Minister, Secretary, Department of Industrial Policy and Promotion, Ministry of Commerce and Industry etc.[76] Other organizations and think tanks such as the The Energy and Energy Resources Institute (TERI) , The centre for science and environment, World institute of Sustainable Development based in Pune but none of them have been highly instrumental in promoting solar energy in India . Trade associations and hybrid institutions in India over the years have failed to legitimize solar energy. Neither media nor public education as well has supported solar energy in India (White et al, 2009).

[76]http://www.thehindubusinessline.com/2010/05/15/stories/2010051551471800.htm

### 9.4 Role of transnational links and international knowledge flows

Indian PV industry has also developed largely due to the presence of global linkages and international knowledge flows. Most of the growth in PV manufacture in India has been oriented towards the export market often to Germany. Some Indian firms such as Moser Baer and Environ are also looking to take up the entire PV chain need access to global knowledge and linkages with companies at the upper part of the PV value chain located in the developed world. It has also been seen that companies involved at the initial stages of the value chain have a vested interest in restricting access to these technologies due to the high cost of building research and production units.

Till recently most Indian firms have acquired technology was through purchasing of necessary licenses or through collaboration with a foreign partner. For example Tata Power, through Tata BP Solar was able to access the knowledge and expertise of BP solar. Moser Baer PV Ltd. is also working in partnership with Applied Materials, a firm that produces solar cell manufacturing equipment. Moser Baer has also gained significant equity in many US based firms such as Solaria and Stion corporation. Similarly many firms acquired technology and knowledge through a large network of Indian scientists and engineers and working abroad. In the past lot of collaboration has taken between Indian and foreign manufacturers through bilateral discussions. Most Indian manufacturers have developed collaborative partnerships ranging from joint ventures to MOU's (Memoranda of Understanding) to informal agreements to accessing networks of Indians engaged in PV research abroad. Many firms have also been able to develop technologies through in house R&D. Eg HHV, a firm involved in thin film solar cells developed the majority of its technology indigenously but the entire process around 10 years. On the other hand Moser Baer was able to start building a thin film power plant in less than 3 years (Ockwell et al, 2009).

However at the same time India is also similarly dependent on developed nations for access to LED technologies which is necessary for rural lighting applications. LED chip manufacturing requires a minimum investment of around 200 million USD, which is capital intensive. LED chip manufacturing involves seven or eight steps with each stage protected by patents. A certain level of indigenous R&D capability is required to access knowledge out of the patents. There are no LED chip manufacturing units in India .Most of the raw materials are imported from vendors in Japan, Taiwan and the USA and assembled by LED system integrators and suppliers in India for various applications. There is only one known LED packaging unit in India i.e. Kwality Photonics. In India very few research institutions are involved in development of LED technology. These include Tata Institute of Fundamental Research (TIFR) Mumbai, CERE Pilani, Indian Institute of Technology (IIT) Madras, IIT Kanpur, IIT Madras, Indian Association for Cultivation of Science (IACS) .However the major problem is that there are no collaborative efforts between research institutions and manufacturers and research has not been commercially viable. Further although the technical competency in India exists in the fields of material science, engineering, control electronics and other relevant fields, they have to be nurtured in the context of LED technology (Ockwell et al, 2007).

### 9.5 Regime

In this section we discuss two major regimes along with the niche regime interactions which have taken place so far

1.Power regime

2.Kerosene regime

3.Instability in the regime

4.Niche regime interactions

#### 9.5.1 Power regime

**Structure of the power regime in India**

Energy sector was nationalized before and during the Emergency in the 1970s. Electricity in India is a concurrent subject at entry 38 in list III of the 7th schedule of the constitution of India. This implies that both the Union and the Indian states have power to legislate on matters relating to electricity. Energy policy in India is scattered throughout many state bodies and organized differently in different states. Each state also has a range of public corporations and development agencies concerned with energy and/or with renewable energy, though state electricity boards have no interests in off grid technology (White, 2009).

The energy sector in India is administered at the apex level by five ministries including the Department of Atomic Energy. Though the planning for the energy sector is done by a single agency i.e. the Planning Commission of India, the implementation of the plan is split across different ministries. In India two main government bodies have been responsible for rural electrification namely Ministry of Power (MOP) for grid accessible villages and the Ministry for New and Renewable Energy (MNRE) for off grid applications unreachable by grid. The rural electrification corporation (REC) a public sector enterprise provides finance directly to electricity boards while the Indian renewable energy development agency finances consumers and providers of renewable energy based services.

Some other important players are the state electricity boards, Power Grid Corporation, Power Finance Corporation public and private sector power producing utilities like NTPC (National Thermal Power Corporation), CEA (Central Electricity Authority) and state Electricity Regulatory Commissions. NTPC is the largest power generation company of India. NTPC currently accounts for about 20% of the country's total installed capacity. Power Grid Corporation of India Limited handles one of the largest transmission utilities in the world. Power Grid Corporation wheels about 45% of the total power generated in the country on its transmission networks. While currently India does not have a unified National grid, the government under Power Grid Corporation is trying to integrate regional grids into a unified national grid ( Bhattacharyya, 2006 ; Green Peace,2010; Srivastava et al, 2006).The structure of the various government bodies is shown in the figure below.

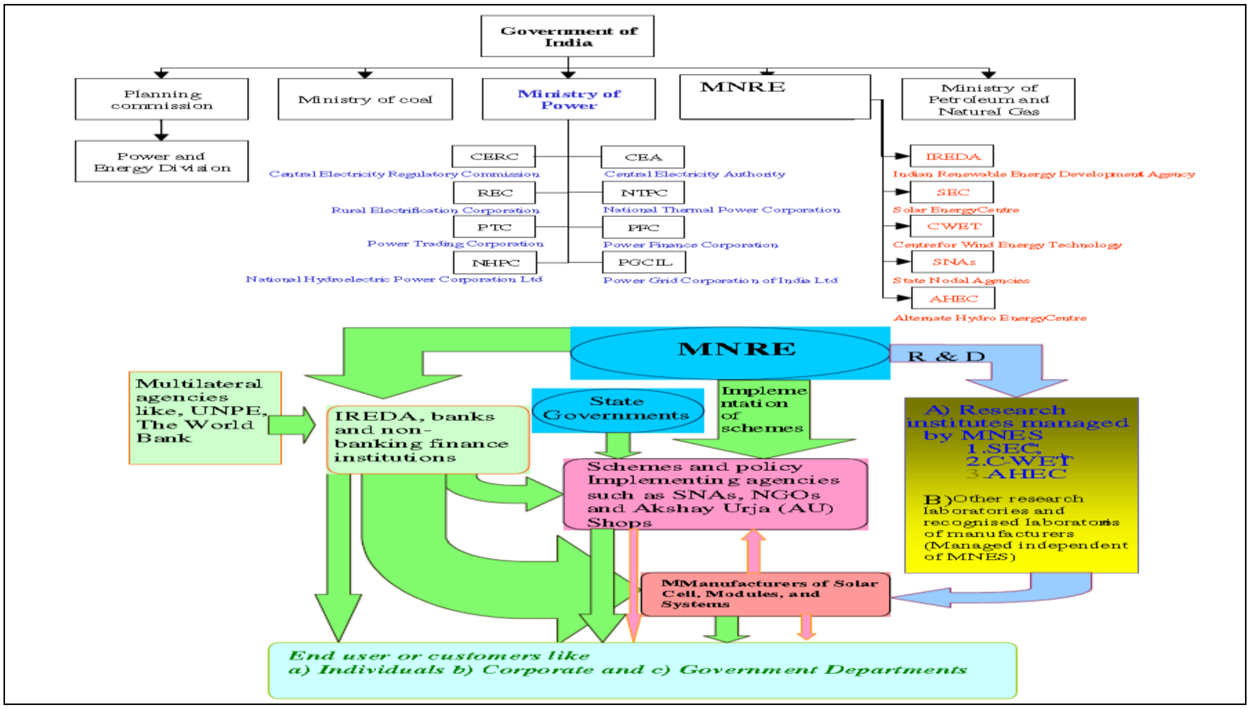


**Figure 9.5:** Structure of Indian power sector (Source: APCTT- UNESCAP, 2009)

**Historical analysis of the power regime**

The power sector in India has undergone radical changes since 1991 by allowing entry of independent power producers. The process of reform of the electricity sector also lead to trifurcation of Ministry of Energy with Department of Power and non conventional sources of energy as separate ministries of the Government of India. With the new electricity laws (Amendment) Act 1991, private sector participation in generation was permitted. In efforts to attract independent power producers, the Ministry of Power waived environmental clearances and failed to provide avenues for renewable energy to fill in the gaps .The second set of reforms began in 1993 saw World Bank setting in where this time the World Bank stepped in to advice on restructuring for greater demand side management.

The Electricity Regulatory Commissions Act 1998 saw the establishment of regulatory commissions at both central and state levels and were entrusted with regulatory oversight in areas of jurisdiction and responsibility of tariff fixation. The Electricity Act 2003 reconciled the various pieces of legislation and is currently the major legislation covering the generation, transmission and distribution of electricity in India. It also replaced the three existing legislations governing the power sector namely Indian Electricity Act, 1910, the Electricity (Supply) Act, 1948 and the Electricity Regulatory Commissions Act, 1998 .The Electricity Act in 2003 mandated state regulatory commissions to specify a percentage of total power consumed to be purchased from renewable energy sources. The new Electricity Act 2003 was the last breakthrough for the reforms in the power sector and also provided better environment for investors in power sector. According to the act any generating company may establish, operate and maintain a generating station without obtaining a license under this act for conventional as well as renewable electricity generation plants (Christiaens, 2008).

There were also state level reforms impacting the power sector which focused on unbundling of the State Electricity Boards (SEB's) into separate generation, transmission and distribution companies; privatization of the generation, transmission and distribution companies; unbundling the State Electricity

Boards (SEB) , making tariff reforms by state governments, enabling legislation and operational support extended to the SEB/utility; improving operations of SEBs, particularly with regard to better management practices, reduction of transmission and distribution losses, better metering and reduction of power theft (Geni, 2006). To deal with various aspects of reforms in the energy sector the planning commission also came out with the integrated energy policy in 2006. The policy focused on making energy markets more competitive, develop market determined energy pricing and resource allocation, transparent and targeted subsidy disbursal and improved efficiency. The Ministry of Power also initiated steps towards efficiency by establishing a regulatory body called Bureau of Energy Efficiency (BEE) for assisting in developing policies and strategies with thrust on self regulation and market principles within the framework of Energy Conservation Act 2001 (Green Peace, 2010).

**Instability in the power regime**

There are several issues which have retarded the growth of the Indian Power sector. Over the year's poor public management, rampant corruption and lack of revenue rendered most state electricity boards (SEBs) in desperate need of reforms. The power sector has faced continued power shortages, increasing tariffs due to cross subsidy, poor quality and reliability of supply. In India in the past highly subsidized power supply policies for agriculture have also had an adverse effect on health of electricity utilities and also overexploitation of water resources. The government in 1960's encouraged irrigation with heavily subsidized electricity during the green revolution in India. The farmer lobby in the county has been successful in keeping the subsidies in place and also has persuaded politicians in few states in India to provide farmer's electricity for free. Thus limited progress has been made in terms of achieving widespread sector liberalization and privatization the reforms to date have not produced desirable political, economic, financial, social or environmental outcomes. Political instability and opportunistic behavior of political parties in India have reduced the acceptability of reforms (Baker & McKenzie and the World Institute of Sustainable Energy (WISE), 2008; Bhattacharyya, 2007; Mishra, 2008; Srivastava et al, 2006).

**Rural electrification in India**

Rural India which is home to around 70% of the national population in India represents one of India's largest energy infrastructure challenges. Electrification rates within villages vary substantially within states of India and have been largely dependent upon source of income and access to the grid. While rural households make up over 70% of the population they account for only 42% of the residential demand for oil, gas and electricity (Rehman et al, 2005). Rural India has also been characterized by small human settlements and given the fact that energy requirements for these settlements are lower than urban and industrial centers there are high costs involved with setting up of transmission and distribution lines in rural areas. Thus it became economically unfeasible to provide electricity to few consumers. Thus rural electrification in India has been financially non viable and also become a large financial burden for electric utilities (Kandpal et al, 2009; Rehman, 2002).

Further the definition of an electrified village in India has also undergone many revisions. The ministry of power has classified a village electrified if electricity is used within the inhabited locality of a census village for any purpose whatsoever. On the other hand MNES considers a village electrified when 60 % of households of households are electrified. Within a given district electrification of a village has also taken place based solely on its physical location and the ability of the population to meet the utility's cost of extending the grid. Most villages where electric grids have been installed have also face problems of infrastructure maintenance. On the one hand state level power sector reforms were launched in many states to increase the financial viability of the sector and on the other hand, increasing electricity coverage to all villages and households in India has been announced as a national developmental goal. Both sets of measures appear divergent in nature and different contradictory goals have thus dominated the power sector in India (Chaurey et al, 2004).

**Historical analysis of rural electrification programmes in India**

The need for extension of the electricity system to rural areas was felt quite early just after the independence of the country. Rural Electrification programme in India was launched with two distinct dimensions i.e. village electrification and irrigation Pump set Energisation. The area of focus was certainly maximizing farm output which did result in the Green Revolution in the mid 1960s. Rural electrification received attention only after the formation of the State Electricity Boards (SEBs) in 1948. The REC (Rural Electricity Corporation) was formed in 1969 to administer central plan outlay and provided loans to the SEBs (State Electricity Boards) and RECOs (Rural Electric Cooperatives) for rural electrification. RECOs were also entrusted with the task of extending the network and providing services in villages. So far 41 RECO's spread over 12 states have been sanctioned by REC out of which 33 are still in operation and 8 have been taken over by SEBs i.e. state electricity boards. Under the influence of the governments and bureaucracy elaborate programmes of rural electrification were made often without planning. An overview of the major schemes is presented.

The Kutir Jyoti (Bright Home programme) scheme was launched in 1988-1989 for poor people living below poverty line without access to energy services. The government bore the entire cost of service connection and internal wiring and is provided to the states as a grant. The funds were channeled through the REC (Rural Electrification Corporation) and the state governments/utilities are responsible for the execution of the programme. According to Rural Electrification Corporation more than 5.8 million households in the rural areas have benefited from this scheme at a cost of 4.5 billion rupees. Under this scheme about 6 million households were connected to electricity in 15 years.

The Rural Electrification Corporation also started irrigation pump electrification and village electrification programmes.REC's acted as a nodal agency for the centrally sponsored programmes and claims to have facilitated electrification of 62% of Indian villages and 59 % of electrified irrigation pumps. The Pradhan Mantri Gramodaya Yojana (Prime Minister's Village Development Programme) was launched in 2000-2001 with an objective of achieving sustainable development at village level and focused on providing basic services for rural electrification. It was co ordinate and monitored by rural development division of planning commission. In this scheme State Board of Electricity/Electricity Department/Power Utilities were given responsibility to implement the scheme. The scheme offered financing through loans (90%) and grants (10%) but was discontinued from 2005-2006 onwards.

To achieve goal of power for rural electrification programmes by 2012 Rural Electricity Supply Technology Mission was launched by the Ministry of Power. The purpose of this mission was to accelerate electrification through both grid extension and stand alone distributed generation options and to encourage decentralized management by rural cooperatives and non governmental organizations (Chaurey et al, 2004). A remote village electrification programme was also started by the Ministry of Non-Conventional Energy Sources (MNES) of Government of India in 2001–2002 for providing electricity access to remote villages where extension of electricity grid may not be possible in the near future. The remote villages were proposed to be provided with electricity supply from renewable energy based decentralized generation options such as small hydro, biomass gasifiers, PV, wind energy conversion systems, hybrid systems etc (Kandpal et al, 2009).

The Minimum Needs Programme was launched for rural electrification in remote areas and less electrified states. This programme provided 100% loans from the central government in the form of partly loan and partly grant. Indian states borrowed funds from financial institutions and received interest subsidies for undertaking rural electrification. The central government reimbursed the interest subsidy provided by the financial institutions and other sources like Rural Infrastructure Development Fund, local area development funds of Members of Parliament etc. Unfortunately this scheme was discontinued in 2004 and further got merged in Rajiv Gandhi Gramin Vidyutikaran Yojna. The Accelerated Rural Electrification Programme (AREP) was also launched in 2003-2004 and was restricted to the electrification of non electrified villages/electrification of hamlets/dalit bastis/tribal villages through conventional and non conventional source of energy. Interest subsidy through the state-utilities to implement this programme was provided. 40% capital subsidy was provided for rural electrification projects and balance amount as a soft term loan through Rural Electrification Corporation (REC). This scheme was also merged in Rajiv Gandhi Gramin Vidyutikaran Yojna (RGGVY) [77].

The Rajiv Gandhi Grameen Vidyutikaran Yojana was launched in April 2005 to achieve National common minimum programme objective to provide electricity to all households. It also aims to achieve 100 % electrification of all villages, provide electricity to all households, free electricity to all below poverty households, decentralized generation system where grid extension is not possible. It aims to develop the rural distribution backbone and to create village electrification infrastructure by installing at least one distribution transformer in each village within next five years. The scheme intends to provide free electricity connection to all rural households lying below poverty line and to provide round-the-clock electricity supply to villages. Under the RGGVY scheme 45602 villages have been electrified and 25087 villages electrified intensively between April 2005 and January 2008. Under the scheme 2287016 rural households that included around 187 6216 below poverty households were given free of cost connection.

The government also started remote village renewable energy programme (RVREP) and grid connected village renewable energy programme (GVREP) .The village energy security programme was meant to electrify and ensure security of un electrified villages and its hamlets by decentralized renewable energy systems. This scheme also ensured to provide 90% of actual cost of the system or INR 2.25 million (around 47000 USD) per system per village of 100 households whichever is less. The remote village solar lighting programme (RVSLP) to distribute single light solar lighting system for remote villages.

Thus a number of programmes were started to enhance electricity access as a part of overall development or specifically targeting rural electrification. However multiplicity of the programmes meant that funding for each of the programmes was not adequate and the programme implementation was not properly co ordinate or managed. Utilities have shown little interest in promoting these schemes due to the financial burden on them (Bhattacharyya, 2006; Deshmukh, 2009). Due to the lack of clear cut policy framework for rural electrification rural electrification using decentralized solutions in India has also stagnated. The government has spend more than INR 40000 crore for rural electrification using centralized schemes but have failed to provide benefits and also has drained huge amount of money in the process. Promise of rural electrification using grid by government has also created problems for grass root organizations and social enterprises in terms of reaching their customers [78]

### 9.5.2 Kerosene regime

A majority of the rural population in India continues to rely on kerosene for domestic lighting. Kerosene based lighting devices used widely in rural areas include kerosene wick lamps, hurricane lanterns, kerosene petromax and non pressure mantle lamps. Even in the electrified households people continue to depend on other energy sources chiefly kerosene for lighting. Majority of electrified households' bulbs in their living rooms but continue to use kerosene based lighting devices in kitchen and for other miscellaneous activities.

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[77] The Rajiv Gandhi Grameen Vidyutikaran Yojana was launched in April 2005 to achieve National common minimum programme objective to provide electricity to all households.
[78] http://business.outlookindia.com/article.aspx?101884

Kerosene has been used for different purposes in two sectors i.e. primarily a lighting fuel in rural areas and as a cooking fuel in urban areas. The fact that kerosene can be used in local home made devices has always been a major attraction for the poorest of the poor However as a lighting source kerosene is not only of poorer quality but is also known to be more expensive than electricity based lighting. Though kerosene has been subsidized to promote its penetration as a clean cooking fuel in rural areas only about 1.3% of the rural households consume kerosene as a cooking fuel whereas as high as 44.4% use it as lighting fuel. Further the emissions from kerosene have an adverse impact both on human health and environment. Kerosene lamps contribute to global warming and the suspended particulates in the smoke cause indoor air pollution with consequential negative health impacts and poses fire and burn hazards.

**Historical analysis of kerosene subsidies**

The system for subsidies for kerosene started way back in 1939 with commencement of Public Distribution System for food. During the period 1939-1945 kerosene was included in PDS system for residential consumers. Since then the Indian federal government has attempted to implement several reforms to reduce and better target subsidies in the petroleum sector, but none have produced the desired results. Some reforms like adding coloured dyes or markers did not succeed because the black market developed techniques to neutralize them. Relatively fool proof systems like coupon systems or smart cards were opposed by the political class. Even the latest strategy which focuses on assigning a unique identification number for each resident of India has created. An overview of various measures taken are presented below.

**Table 9.2**: Overview of reforms and measures taken with respect to kerosene subsidies (Source: Shenoy, 2010)

| India's fossil-fuel subsidies: A timeline | |
|---|---|
| 1939 | Commencement of the Public Distribution System (PDS) for subsidized food |
| | Domestic oil prices based on import parity |
| 1939–1945 (WWII) | Subsidized kerosene included in PDS for residential consumers |
| 1948 | Fixed petroleum refining and dealer margins established |
| Late 1960s | Subsidies for liquid petroleum gas introduced for residential consumers |
| 1976 | Petroleum prices fixed under the Administrative Pricing Mechanism |
| 1980s | First attempt at marking subsidized kerosene with dye |
| 1989 | Coupon system introduced to control access to subsidized kerosene in Mysore (program closed two years later) |
| 2002 | APM dismantled; petroleum prices (other than residential kerosene and LPG) liberalized |
| 2003 | Government intervention in petroleum prices |
| 2005 | Global positioning systems fitted to kerosene distributor trucks in an attempt to prevent diversion of fuel (program closed in 2008) |
| 2006 | Marking of subsidized kerosene with a dye to prevent diversion of fuel (program closed in 2008) |
| | High-level committee "Rangarajan" report recommends liberalization of petroleum product prices (recommendations involving the market prices not implemented) |
| 2007 | "Smart cards" considered to control access to subsidized kerosene (program not adopted) |
| 2008 | Government "Chaturvedi" report recommends liberalization of gasoline and diesel prices and changes to fuel tariff and taxation regimes (recommendations not adopted) |
| 2010 | "Parikh" expert group recommends market-oriented pricing (government action pending at the time of writing) |

**Instability with respect to kerosene regime**

Kerosene prices over the years have been controlled by the government and are heavily subsidized .About 90% of rural kerosene is distributed through a Public Distribution System (PDS) comprising state and district level officials, wholesalers and retailers .The Ministry of Petroleum and Natural Gas fixes a quota for each state according to historical patterns of supply. The allocation varies from state to state and is based on historical patterns rather than on demand or on consideration of relative poverty levels .At the state level the Department of Food and Civil Supplies (DFCS) does the district-level and retailer-wise allocation on the basis of the advice received from the Oil Coordination Committee (OCC). Private operators are free without constraint to import and sell kerosene at market prices. Generally kerosene supplies intended for distribution through the subsidized public distribution system have been illegally diverted to the black market for mixing with diesel stocks.

Hence rural poor regularly have been buying 150 % to 300 % of the subsidized supply for kerosene. The diverted supply has been resold to households at prices higher than the subsidy price or used by the non household sector. Thus after providing subsidies on kerosene the Government of India has not been able to bring a meaningful change in the energy consumption patterns of Indian households especially the poor and rural households. Kerosene is also highly inefficient source of lighting as compared to electricity and the subsidy on its consumption has not been intended to provide the fuel as a light source. Its use as a lighting energy source limits its use for meeting cooking energy needs resulting in continued dependence on biomass with all problems.

Thus the indented kerosene subsidies for poor have not reached the poor and it is the affluent and the already electrified which have consumed the highest amount of kerosene. Similarly the scheduled castes and tribes who form the lowest rung of the social ladder (below poverty line BPL families) for whom the subsidy schemes have primarily been established are the lowest recipients of the subsidy. Thus the high level of subsidies on kerosene have been ineffective in promoting equitable access for energy. High levels of imported kerosene have also caused financial burden on the government (Chaurey et al, 2009; Gangopadhyay et al, 2005; Morris et al, 2006; Reddy, 2009; Rehman et al, 2005; Rehman et al, 2010).

**9.6 Niche regime interactions**

In 1993 guidelines for procurement of power from renewable energy sources from renewable energy sources were developed. MNES also issued guidelines for purchase of renewable energy sources by Indian state utilities. Several state nodal agencies were established in different states like GEDA, TEDA, MEDA and played an important role in accelerating renewable energy. The central electricity authority commission and state electricity authority commissions also played an important role in deciding renewable energy quotas for RPO obligations and renewable electricity tariffs (Chaurey, 2001). In 2001 the central government passed new energy legislation that called for the increased provision of renewable energy in order to meet rural energy needs and provide decentralized off grid energy supply for the agricultural, industrial, commercial, and household sectors in rural and urban areas (Radulovic, 2003).

The government also enacted two necessary major laws, the Energy Conservation Act 2001 and the Electricity Act 2003. Sections 61(h) and 86(1) (e) of the Electricity act 2003 stressed on renewable electricity programmes. The Electricity Act 2003 section 86 required states to set renewable energy targets by ensuring grid connectivity and sale of renewable electricity. The section created a demand for renewable energy by requiring State Electricity Regulatory Commissions to specify percentages for renewable energy for purchased within the area of a distribution licensee. The national tariff policy also required all state electricity regulatory commission to specify minimum percentages for electricity to be purchased from renewable energy sources.

In 2005 the national electricity policy assured improved access to electricity, power, reliable and quality power of specified standards in efficient manner and reasonable rates, improving commercial viability of sector and protection of consumer interests. In 2006 the national tariff policy fixed a minimum percentage of energy to be purchased from renewable energy sources by utilities. Further in 2008 national action plan for climate change was launched through 8 national missions. The National solar mission focuses on increasing use of solar energy for large scale electricity production, distributed electricity production and development of solar industries. In April 2010 introduction of renewable energy certificates and RPO quotas through central electricity regulatory commission was proposed (APCTT- UNESCAP, 2009; Christiaens, 2008; Singh, 2006; White et al, 2009).

In August 2006 the government announced integrated energy policy report with aim of providing guidance for India's energy policy. The report takes an in depth looks at energy security and various policy options (e.g. subsidies, taxation). The report scrutinizes relevant energy issues including household energy security, coal and power sector policies, energy R&D, environment and energy linkages, energy efficiency or demand side management policies as well as policies for renewable and non conventional energy sources (Ockwell et al, 2009). In recent times the central government has also delegated certain powers to the States for expediting the implementation of small projects. The State Governments have been encouraged to promote commercial development in the renewable energy sector through policies with respect to banking, wheeling and third party sale of electricity. As per the MNRE directives, various State Governments have formulated policies for the promotion of renewable energy technologies and projects through the state nodal agency of MNRE or the state department of energy.

Although India has had a ministry dedicated to renewable energy for many years it still does not have a separate mandate and national level law to look at increasing renewable energy. The Government is also in the process of developing a specific renewable energy law. In June 2008, the Prime Minister authorized the MNRE to draft schemes to prepare draft legislation for the promotion and accelerated growth of the renewable energy sector. (Baker & McKenzie and the World Institute of Sustainable Energy (WISE), 2008)

# Appendix B: Upscaling of experiments

## 10.1 SELCO, Bangalore

### 10.1.1 Introduction

SELCO Solar Pvt. Ltd, a social enterprise established in 1995 provides sustainable energy solutions and services to under served households and businesses in India. SELCO was founded by Harish Hande and Neville William. It was formed to clear three myths i.e. poor people cannot afford sustainable energy technologies, poor people cannot maintain sustainable technologies and social ventures cannot be run as commercial entities. Many of SELCO's customers have been traditionally dependent on the potentially hazardous kerosene for their lighting needs. SELCO offers door step service in conjunction with door step financing, empowering the underserved by offering a combined package of technology, finance and client services for energy services predominately for income generating activities based on specific needs.

### 10.1.2 Historical Background

During the initial phases i.e. around 1995 onwards Harish Hande of SELCO spent two and a half years living in a rural Indian village without electricity, considering the opportunities that lighting would bring and understanding the specific requirements of poor families. His vision was to enable poor people to access appropriate and affordable lighting. SELCO lacked investment capital hence Harish Hande proved his business concept by purchasing and adapting one solar lighting unit at a time, selling it and reinvesting the money to build another unit. Harish Hande did this process 500 times over three years with his initial investment until he was able to access a loan for one million dollars from the International Finance Corporation (IFC) which enabled him to produce enough units to sell at a larger scale. During the incubation stage Harish Hande also lacked technical and business advice. Luckily he was able to have access to mentors and lessons from other entrepreneurs. The initial years were also difficult financially and SELCO just could barely manage to give the technicians salary. In and around 1996-1997 SELCO received 3 year grants from World Bank and IREDA. Later on after securing USD 1.1 million in an initial equity investment, SELCO began investing in building a market for solar lighting technology. Thirteen investors including wealthy individuals, social-venture capitalists and social venture funds from Europe, put money into a U.S.based entity which reinvested the funds in SELCO India.

When SELCO started banks did not lend money to poor for only income generating activities such as fuel and agriculture within specific time frames. Most banks were not convinced for lending loans for sustainable energy technologies as they believed that they did not lead to income generation. Most banks didn't have the infrastructure to collect money on a daily basis. Although microfinance institutions did that they charged heavy interest rates and making them as expensive as professional money lenders. For the customers rather than relying on subsidies SELCO decided to convince banks financial institutions, Grameen banks, rural banks and credit co operations to invest in solar energy for flexible financial solutions meeting cash flows of poor people.It took Harish Hande almost five years to demonstrate that this kind of financing could work and his perseverance paid off. In 1996 SELCO was able to convince the Malabhraba Grameena Bank a subsidiary of the state owned Syndicate Bank which offered India's first solar consumer loan program. Initially SELCO began providing PV systems for the Bank's over 200 branch offices. SELCO then arranged for the training of bank employees regarding solar energy and soon the financing by bank branches of PV systems for rural households commenced. It also held several such training programmes to build the market for people interested in acquiring solar lighting and to manufacturers interested in producing the products and has trained almost more than five thousand rural bankers.

SELCO also created first service centers in and around 1995-1996 hiring local youth and promise of service within 24 hours. During the time period between late 1997 and 1998 SELCO received financial assistance from Bank in Dharwad for training bank managers about customizing financial packages for BOP clients. SELCO also started having some profits from 1999 around and has also seen incredible growth since 1998.

In 2005 a new national solar subsidy program in Germany was a big market opportunity for Indian solar module manufacturers which turned their focus away from supplying local companies. SELCO faced lot of problems due to this scheme as the prices for solar panels increased drastically by 46%. The panels also took three to six months which were previously taking 15 to 20 days to be delivered. SELCO therefore decided to increase the number of suppliers and variety of products and also diversify into other energy services.

### 10.1.3 Upscaling mechanisms for SELCO

**1. Vision, mission, ambition and expectations**

SELCO's long term mission is to create linkages between income generation and sustainable energy services, develop a range of energy services for the poor.

**2. Learning in terms of development, financing and implementation of business model**

Here learning focuses on encouraging double loop learning in terms of developing a viable business model by challenging the conventional wisdom such as poor cannot afford sustainable energy technologies, setting up partnerships, undertaking learning and experimentation and being financially sustainable. Here we also describe how SELCO developed its learning strategies for meeting the energy needs of the poor.

**1. Products and services**

SELCO's products include photovoltaic solar home systems that generate power from a rooftop solar panel to provide lighting or operate radios, cassette players and fans. The batteries are designed to run the loads for specific periods even during the heavy monsoon season. 80% of sales on households' products include SHS (panel, battery and charge controller for 2 to 4 lamps and a 12V plug) and individual solar lanterns. SELCO sells solar lighting solutions using both CFL and LED lamps, solar thermal systems (water heaters), solar inverter and cookstoves.The solar home systems are sold at around 300 USD with credit facilities (15 % up front and then 6 USD over 5 years).Solar lanterns can be bought for USD 12 (over USD 2 per month). SELCO has even set up a rental scheme for non bankable urban poor such as vegetable vendors, street hawkers who can rent batteries for lighting on a daily basis at (USD 0.06 per day). SELCO also designs larger/commercial systems to meet specialized applications. It also provides services such as custom system design,installation,training on proper system use and after sales maintenance and support.

**2. Infrastructure management**

SELCO operates in the lowest part of the PV value chain i.e. balance of systems and focuses on installation and customer services.SELCO's core competency lies in customization of technology by providing the right combination in terms of customer needs, finance and appropriate technological solution. It also believes that there are enough companies developing PV technology and SELCO is instead focusing on bringing the products to people at the Bottom of Pyramid through professional installation/ service and local financing mechanisms .SELCO provides high quality experience for end users even though they are expensive since the systems developed by SELCO last longer and are price competitive. For development of solar home systems SELCO gathers PV panels and batteries from different wholesalers, distributors depending on who gives most competitive price. Controllers and wiring are purchased from Anand electronics based in Bangalore and all the parts are assembled to develop a complete system. SELCO initially had problems with the quality of CFLs and lamps used in systems and hence it had to set up a sister business to manufacture both CFLs and charge controllers.

**Operational structure**

SELCO's head quarter is in Bangalore which is responsible for overall management of SELCO's operations. The headquarter also provides all accounting and managerial oversights. Each RBO has 1 to 5 ESC (Energy service center) under them. SELCO also relies on institutional support in form of local NGO's,banks and institutions for providing support for human resources,trainings,financial resources etc.When moving into new areas, local NGO's also support SELCO in getting office space, staff recommendations, resource recommendations. The regional branch offices operate its service territories to supply, administer and manager energy service centers. The regional branch offices also supplies components for solar home systems and as a contact point between SELCO headquarters and service centers. The energy service Center (ESC) is the basic building block of the SELCO's rural operations. Each ESC has a service territory in which it markets, sells, installs, and services SELCO's energy services New centers are opened only when there is a real demand for systems and when local financial institutions are able to provide financing arrangements to poor.. Through these energy service centers SELCO reaches into the smallest and most remote communities. The organization currently has 25 centers. Each center typically employs five people who do everything from promotion, sales, and installations, to follow up service visits to ensure that the systems installed by SELCO are working correctly. The operational structure is also shown in the figure below

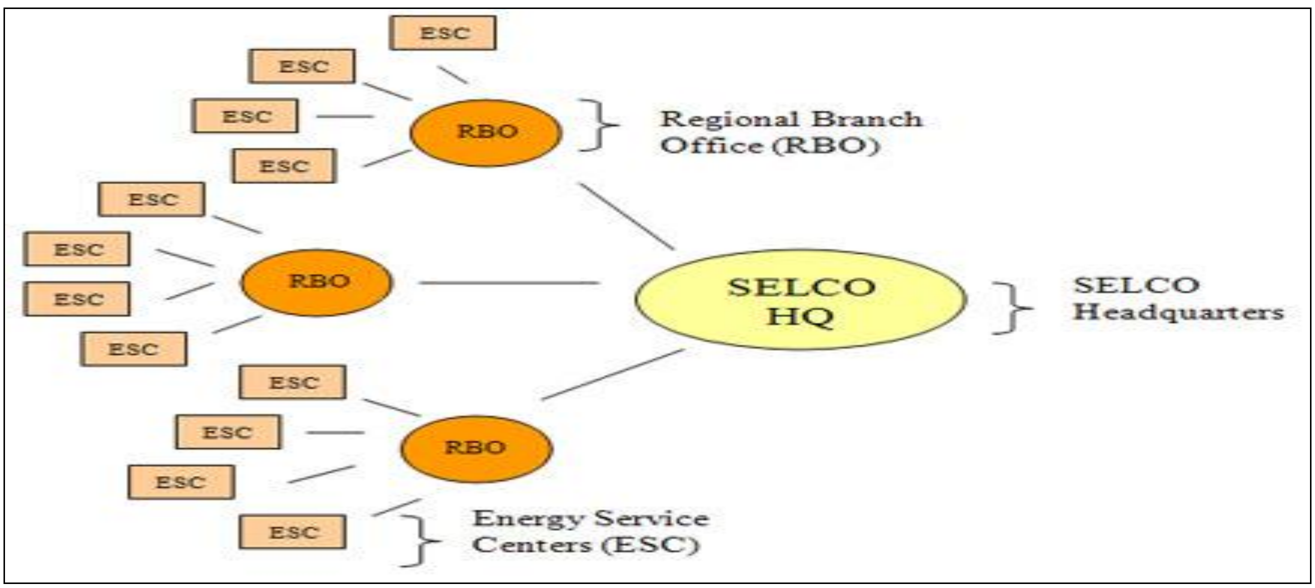


**Figure 10.1:** Operational structure of SELCO (Source: SELCO)

Each service center has a show room of SELCO products. Service staff in the center need to cover a 25 to 30 km radius reach base of 1000-8000 people and achieve sales of around USD 6000-20000 per month. Each service center is run by 5 staff members (2 sales manager. 2 customer support members ,1 administrator,2 technicians,2 sales personnel, one accountant and one manager).5-10 business associates are also involved in the operations. All energy service center hire staff members from local communities for building trust and capacity within communities and also remove case barriers.

The main work of SELCO is carried out by local service centers. Each centre keeps a stock of components and equipment, and has clear operational requirements, and monthly targets for both number of systems sold and financial turn over. Service centre managers report daily by email to head office and have weekly and monthly meetings and this close liaison avoids many operational problems. Within each center roles are clearly defined. The sales agents are responsible for promoting the business, visiting potential customers, designing systems and taking payment. The technicians install and maintain the systems but do not deal with any financial matters.SELCO also focuses on making each center financially viable. They also deal with sales to entrepreneurs who hire out batteries.

**3. Customer interface**

SELCO over the years has focused on customized energy solutions which did not happen initially during the demonstration programmes by government bodies. Most government programmes had installed solar lights in villages but never paid attention to maintenance and services. This also made people lose faith in solar energy technologies and it also took several years for SELCO to change the mindset. SELCO has focused on creating products based on end user needs and going just beyond a technology supplier and customizing products based on individual needs; maintaining installation and after sales services by setting up dedicated regional energy service centers for maintenance and services and creating financial packages for end users to afford solar products based on their cash flows, income cycles and spending and living habbits of people. SELCO also helps poor people find customers and market linkages for selling their products so that they can afford solar energy solutions with the increased income with the use of solar energy products and services.

SELCO also made sure that it did not sell solar energy systems in an area where it could not service. This approach also helped SELCO maintain its lead over competition despite its solar energy systems being the most expensive in the industry. Over the years SELCO has developed substantial infrastructure for marketing, sales and service with multifaceted employees who can manage multiple tasks such as customer needs assessments, technical issues and financial issues. For attracting its customers SELCO has also relied on word of mouth marketing by engaging local people in the communities who also get a commission for bringing in new customers. Further it has relied heavily on local people various religious and faith based organizations in and around Karnataka for attracting new customers.

**Customized solutions**

SELCO has been the pioneer of highly customized solutions for energy for people at the bottom of pyramid. For example it has mounted lights in the corner of one room and remove bricks into other rooms, so that a single light provides background illumination in three rooms. Another feature designed by SELCO is developing  a flexible low cost lighting systems which can be moved from one place to another in the same house and installing the wiring and brackets for six lighting points in a four light system. Similarly SELCO has developed customized systems have been sold to stallholders in street markets which need less individual lights but with higher illumination, solar headlamps for rose pickers , customized lights for silk farmers who use kerosene lamps to check on their worms at night despite the danger that a single drop of kerosene would kill the worms. In terms of financing solutions SELCO does not provide credit or loans but has built up working relationships with local banks and microfinance organizations for users to avail its products and services. SELCO has piggy backed on this extensive rural credit network. Today SELCO shares a solar loan portfolio with all the major public sector banks in Karnataka-Syndicate Bank, Canara Bank, State Bank of Mysore, Corporation Bank and Grameen Kota Bank.

All installations  and user training are carried away  by SELCO technicians .SELCO  provides 10 year guarantee for PV panels and 3 year guarantee for batteries. It also provides 90 day money back guarantee with one year free service. SELCO staff visits once every three month to make sure that solar systems are working properly. All SELCO service centers hold full stocks of spares, so that replacements can be made quickly if there is a problem.  Users also have the option of including the cost of a second battery via slightly higher monthly installments so that they are not faced with the cost of a replacement battery just when their loan has been repaid. This ensures that the replacement battery is a proper PV battery rather than a cheaper car battery. SELCO also makes sure that batteries are returned to SELCO for recycling.

SELCO helps its customers to obtain the necessary credit to purchase solar lighting and thermal systems. Through rural financial institutions on terms that work for them. Loan sizes range from USD 100 to USD 350. Most people who buy systems from SELCO are required to make a down-payment of typically 15% of the cost. SELCO also has set up a guarantee fund to cover initial 15 % for non bankable poor customers. Customer financing schemes are  provided by partner banks at 13% interest. Some users work directly with the finance organisations, others work through self-help-groups which provide additional security that a loan will be repaid. SELCO's financing mechanism is also shown in the figure below.

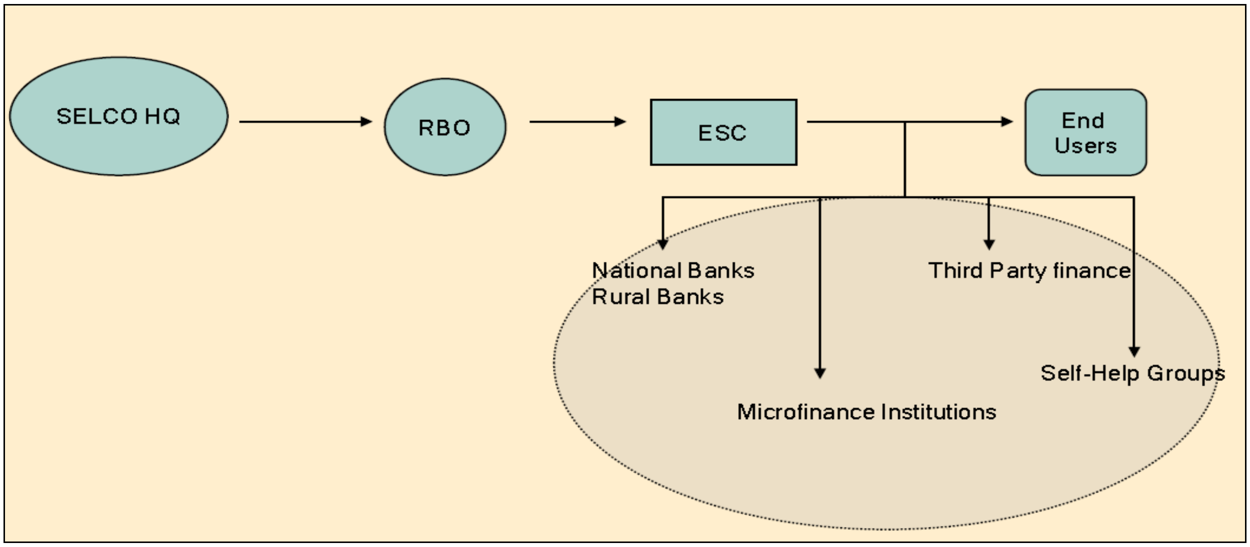


**Figure 10.2:** SELCO's mechanism for developing customized financial solutions (Source: SELCO)

SELCO also insists on a service agreement to assure that the solar systems  work for a  long time  after initial installation. SELCO has also  reduced burden on financing through interest subsidies and using indirect funds  and non budget subsidies like carbon offset to reduce costs of the system and also subsidize operational costs which otherwise add to the costs to the system. SELCO develops payback mechanism for the loan for the user depending upon the cash flow of the user. For example if the borrower is a farmer payment is done in relation to the harvest schedule, street vendors pay on a daily basis, and women working from the home pay according to their product sales. Thus  such financial mechanism have also given finance organizations the confidence to provide credit for PV systems and an understanding of the payment terms which different owners may need at the door step.

**Relationship with SEWA Bank**

SELCO has also developed extensive partnerships with micro finance institutions such as SEWA bank. SEWA Bank offers loans for solar home lights, solar lanterns, and battery charging systems and also promotes smokeless cook stoves, solar cookers, and sarai cookers which are available on a cash basis to clients such as household consumers, hawkers and energy entrepreneurs. According to the partnership agreement energy clients must have a open or savings account upon taking an energy loan in SEWA bank. SELCO offers free maintenance and operation during the warranty period which also varies with product. SEWA bank markets the products through its existing promotional channels such as mobile vans and displays in monthly fairs and through some of its other parent NGO programs.

In the process SELCO assesses clients' needs to help them purchase the least costly and best suited energy option. A compulsory 15 day trial period for energy technology is offered during which SEWA Bank ensures clients are satisfied and voluntarily buy the products based on genuine need. SEWA Bank disburses payment directly to SELCO which then becomes the liability of the client.SELCO then installs the system and provides user training at time of installation as well as during business counseling hours.
Installation and Training: SELCO installs the system and provides user training at time of installation as well as during its business counseling hours.SELCO also offers free after sales service during the warranty period.SEWA bank has also employed commission loan agents known as Banksathis which collect loan repayments from clients on behalf of SEWA bank. The partnership between SEWA bank and SELCO has also provided a one stop shop for clients by combining energy efficient products with a credit facility in one location. In future SELCO is also planning to market to SEWA's network of women and engage them both as end users who will purchase the technology directly and as micro entrepreneurs who will launch small solar lighting and other energy service businesses.

In addition SELCO also operates a franchise model and has created a network of SELCO entrepreneurs .The small entrepreneurs run a micro enterprise unit of charging and renting out solar lanterns to village households on a daily rental basis who do not have access to safe, clean quality lighting. The microenterprise rents out solar lanterns which are run on batteries charged by SPV panels. Fully charged lanterns are delivered to the households in the evening so that they can enjoy clean and efficient lighting at night and returned/ collected in the morning for daytime recharge using SPV. In the case of the street hawkers these energy entrepreneurs charge up to around INR 12 for charge. In this mechanism while SELCO's energy entrepreneurs benefit from the hawkers' rental fees the hawkers themselves save money on the purchase of kerosene and cut down on the smell and fumes which can damage their products.

**4. Financial aspects**

SELCO over the years has tried to maintain its financial viability by running like a commercial firm but also maintaining its social objective..The main source for SELCO's revenues is from the sale of its products and services. SELCO's initial funders included the Rockefeller Foundation and Solar Energy Light Fund, a US-based non-governmental organization that promotes solar lighting. SELCO received a funding of INR 5.5 million from Winrock India in 1996-1997 provided under the USAID renewable energy commercialization project and letters of credit totaling INR 2.9 million from World Bank GEF. SELCO also received USD 850000 in equity from SELCO USA between 1997 and 2000.SELCO's largest loan was from IFC backed PVMTI which approved USD 1 million in 2003 for working capital for inventory and expansion and as guarantee to back expansion of PV consumer financing through Indian Banking system.In 2009 SELCO attracted social investors such as Good energies foundation, Lemelson foundation and E+CO recently for funding.

In terms of financial sustainability SELCO became profitable between the time period between 2000-2005 but suffered heavy losses due to 45 % increase in panels due to subsidy programmes in Germany and other European nations. In terms of revenues SELCO earned revenue of USD 3.1 million revenue in 2008. It has generating sales of INR 12 crore in the fiscal year 2009 with a target of increasing revenue to nearly INR 40 crore by 2014. The annual turnover for SELCO has generally been almost USD 2 million and profit margins have been 20-26 %.

SELCO has also earned revenues by selling carbon credits. Since 2002 SELCO has also sold 4500 tonnes of carbon dioxide to Britain-based Carbon Neutral, though it has also saved roughly 28000 tonnes of $CO_2$ equivalent per year by helping poor families scrap the use of smoke emitting kerosene for lighting. Since SELCO deals with selling lighting to poor households which do not that really do not emit much greenhouse gases (GhGs) SELCO also found the process of selling savings on carbon dioxide emissions through Kyoto Protocol's CDM too expensive and time consuming.

**5.Fit of the business model**

Although SELCO's model has been highly successful but it faces several problems. Some major issues high variability in the price of components i.e. cost of the installed system, PV modules, replacement batteries and converters for solar home systems. In this respect SELCO faced lot of troubles and heavy losses as discussed before during 2005-2006 when prices for solar panels increased drastically. SELCO later on diversified to other products and services and other energy services so that fluctuations in prices of solar energy products does not hamper its financial sustainability and the risks are reduced.

Another important threat is grid extension since false promises by government of grid electricity destroys the market created for solar energy. SELCO is also highly dependent on existence of a supporting ecosystem including microfinance for customers due to high upfront costs, investor finance for the enterprises themselves, trained local technicians and favorable regulations from government.

### 10.1.4 Human resources and partnerships

SELCO has 25 people in head quarters in Bangalore and 125 in various service centers. SELCO currently employs about 140 employees in Karnataka and Gujarat spread across 21 energy service centers. SELCO's management also has collectively over 44 years of grass root experience in field of providing sustainable energy services to the under served. SELCO has a core team of 4 regional sales managers, 8 senior managers, 21 branch managers, 32 sales executives, 40 customer support executives and 18 office administrators in addition to other members for projects, innovations and finance departments. The operation of SELCO has provided valuable employment opportunities. The total number of employees is about 170, of whom about 145 are in the 25 local service centres of which the staff is recruited locally.

SELCO is headed by Dr Harish Hande who is the managing director of SELCO India.Mr Thomas Pullenkav is the vice president,Mr Ashish Kumar Sahu as the chief operating officer,Mrs Revathi as chief financial officer and vice president.SELCO also has an incubation lab which is headed by Mr Anand Narayanan.SELCO operates through a decentralized organizational structure that connects the headquarters to customers through not only regional offices, but also local Energy Services Centers (that provide sales, marketing, installation and services in central rural towns) and Business Associates that sell directly to customers. SELCO's organization structure is shown in figure 10.3 below.

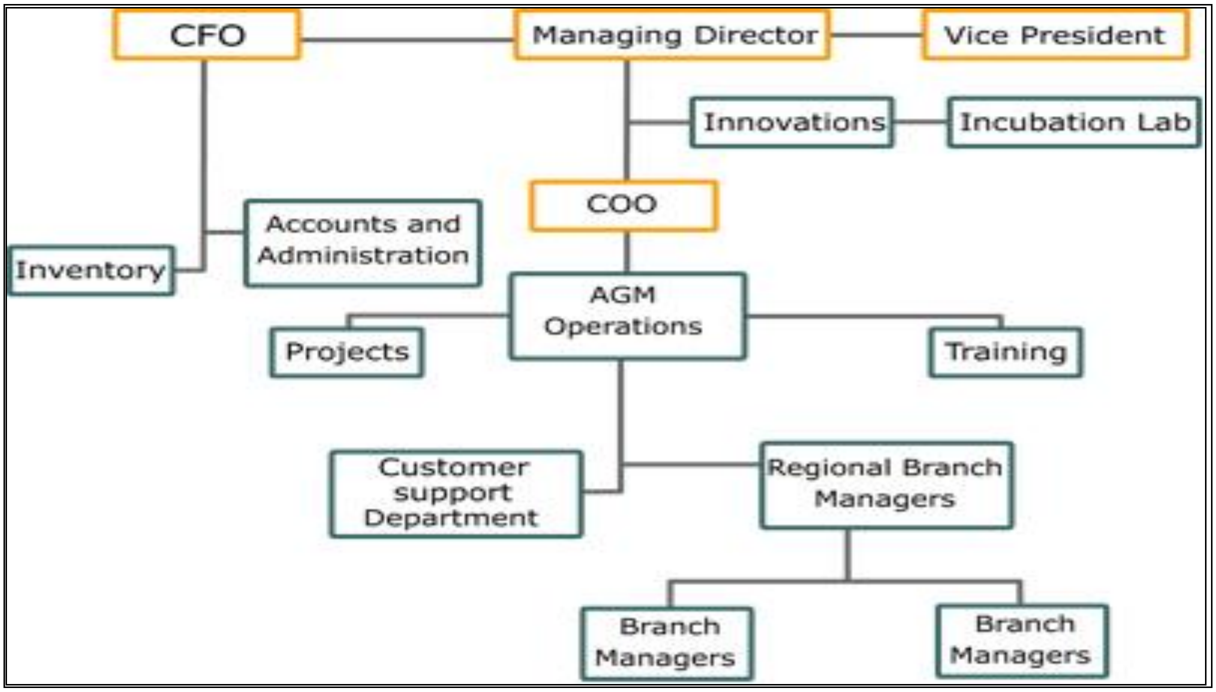


**Figure 10.3:** Organizational structure of SELCO (Source: SELCO)

SELCO has also formed partnerships with a number of organizations such as MIT Design labs, Engines and energy conversion lab at Colorado state university; community based organizations such as Bhartiya Vikas Trust, Bangalore rural educational and development society (BREADS), Shree Kshethra Dharmasthala Rural Development Project, (SKDRDP); 42 banks and financial institutions of which some prominent names are various financial institutions such as Syndicate bank, Karnataka Vikas Grameen bank, Vijaya bank, Canara bank, Pragathi Grameen bank, Krishna Grameen bank etc; carbon trading companies like carbon neutral for services such as carbon offsetting and carbon consulting; holistic organizations like SEWA bank with project Urja for joint partnership built on offering unique low interest energy loan portfolios between ; academic institutions such as Manipal Institute of technology, INSEAD, MIT Sloan school of management, Columbia business school, Stephen M Ross School of Business, University of Michigan and Indian Institute of Management, Ahmedabad; international organizations such as Global village energy partnership (GVEP), Renewable Energy and Energy Efficiency Partnership (REEEP). In addition SELCO has also formed partnerships with organizations like UNEP, Clinton global initiative, Ashden Awards, Clinton Global Initiative and Nand and Jeet Khemka foundation.

### 10.1.5 Gaining legitimacy

SELCO has gained legitimacy by becoming a reliable energy solutions provider and developing linkages with range of local, national and international stakeholders . It also developed a good reputation with suppliers of components and other local, national and international stakeholders. Further SELCO developed its cognitive legitimacy by developing new ways of meeting energy needs in terms of customized solutions of poor which were done before. SELCO has also received a large number of awards from reputed organizations which has also been useful in enhancing SELCO’s legitimacy.

SELCO won the Ashden award for sustainable energy in 2005 as well as 2007. Harish Hande also won the social entrepreneur of the year in 2007. SELCO has also received the Accenture Economic Development Award from the Tech Museum Awards in 2005 in recognition for supplying power to rural India and its application of micro financing opportunities for its customers to pay for the service. In 2007, Harish Hande received the Social Entrepreneur of the Year Award by the Nand and Jheet Khemka Foundation, UNDP and CII. Harish Hande has also served as the board member of International development enterprise, advisory board member of Karnataka renewable energy development, International Rural Energy Delivery Service Group, S3IDF South Asia, Global Village Energy Partnership (GVEP) and membership of other organizations such as Ashoka, Schwab Foundation and Ashden Awards. Thus all these recognitions have established SELCO as a credible organization.

#### 10.1.6 Barriers to upscaling

SELCO faces barriers due to regulations regarding working capital from financial institutions. Margin money or down payment is required as per RBI regulations for disbursing a loan and for many families even 15 % is a very high amount. If the poor have proper land documents and assets as collateral then they do not need to show them for loans below INR 25000 however most financial institutions are hesitant to take risk as non payment can affect their loan repayment and track record. Most applications for loans get rejected and a third party needs to come in which can persuade the banks to lend. Even if financial institutions are ready to customize a loan product for renewable energy services then road block is high interest rates. SELCO faces barriers in raising capital with high risk and low returns from social investors as well as end user financing schemes. In addition SELCO also needs funds for financial and technical innovations. It also faces barriers in finding right talent in terms of staffing problems with constraints of such as high salaries, work environment and finding people who can think holistically.

In addition to this high VAT (Value added taxes) for users on sales of solar home systems also create barriers for SELCO. Apart from that some other barriers include  inefficiencies of electrical products for example solar system powering an inefficient sewing machine. The solar systems are blamed instead of the inefficient machine. The design of renewable energy products need to match efficiency of inefficient products which also increases the cost and time to develop such products. Therefore there is also a need for developing solar ready label for electrical appliances to overcome such barriers.

#### 10.1.7 Upscaling performance in different dimensions

**1. Quantitative**

SELCO has provided sustainable energy products and services provided to more than 100000 households.SELCO has also supported 110000 rural homes, 2000 institutions and 10000 small business cottage industries.The number of installations of SELCO over the years are shown below in the table.

**Table 9.1:** Number of installations of SELCO over the years (Source: SELCO)

| Year | # of Installations |
|---|---|
| 1995 | 150 |
| 1996 | 345 |
| 1997 | 900 |
| 1998 | 1150 |
| 1999 | 2450 |
| 2000 | 5400 |
| 2001 | 8500 |
| 2002 | 9100 |
| 2003 | 11034 |
| 2004 | 12500 |
| 2005 | 12350 |
| 2006 | 7800 |
| 2007 | 8560 |
| 2008 | 9600 |
| 2009 | 13200 |
| 2010 | 20000 |
| 2011 | 22000 |
| 2012 | 25000 |
| 2013 | 30000 |
| Total | 200039 |

## 2. Net impact

Through provision of solar lighting solution, SELCO has been able to improve productivity and successfully empower individuals to run their businesses without dependence on fuel based products SELCO has also been instrumental in creating faith in solar power. By linking income generating activities with energy services SELCO has improved the quality of life for several people by providing affordable channels to procure technology and improving quality of their life.

## 3. Organizational

SELCO has had a successful growth over last 14 years to a $1.75 million turnover in FY 2009 and estimated $3 million FY 2010. SELCO has more than 170 employees currently.SELCO's expansion plans include achieve an annual turnover of USD 6 million in future.

## 4. Geograhical

SELCO identifies local roots, tailor made installation and customer service as key success factors and is not aggressively planning to upscale geographically. Instead it wants to focus on customization since problems of a household in one village in a region are entirely different from other. SELCO also feels that if it scales in the traditional way then it may lose sight of its mission. SELCO has also found it difficult to expand to other states due to lack of spill over learning in different states.Eg it has been difficult for SELCO to convince bank employees in other states. SELCO also does not want to use the franchise system to sell its products and services as the reputation of their brand depends on services and it is more difficult to guarantee same level of services from the franchises. Hence SELCO has decided to only move to a new region if they have good contacts there both for dissemination of information and for providing finance. SELCO is focusing on expanding geographically in five Indian states neighboring to Karnataka i.e. Maharashtra, Tamil Nadu, Kerala and Andhra Pradesh.

**5. Depth**

SELCO is looking to upscale in terms of reach people who earn INR 1000 or less a month. It has also set up rental schemes for non bankable poor such as (Vegetable vendors, Street Hawkers) who can rent batteries on daily basis.

**6. Functional**

Like many small and medium sized businesses, SELCO grew by focusing on its core market of solar home systems. New solar-related businesses which the innovation department has helped with technology, business planning and securing finance include: PV-powered battery-charging businesses which supply single-lamp systems for both street vendors and poor homes; PV-power for sewing machines, to increase the productivity of sewing businesses; PV-powered soldering irons for TV repair; and small PV-powered silk looms. SELCO is also in the process of developing a cheap, improved cook stove for its clients. SELCO has not only developed the ability to sell and service solar lighting systems but in the process of developing other energy services. SELCO is also in the process of diversifying to other energy services apart from solar energy services such as thermal, cooking, biogas, dryers to its existing clients. Thus SELCO is looking to become a complete energy provider from just a solar lighting provider.

**7. Replicaiton**

SELCO is trying to upscale by replication by starting an incubation system for new entrepreneurs. Young entrepreneurs can start their own enterprise by keeping SELCO as board advisors. It is also willing to set up a USD 3 million fund to help new entrepreneurs planning to start new enterprises for energy services in different geographical locations. Over the years SELCO has helped to create more than 25 entrepreneurs who are serving 750 clients by providing solar lighting to street vendors, home based workers and small businesses.

**8.Innovation**

SELCO has started an incubation lab. The incubation lab is the research and incubation arm of SELCO which was started in April 2009. The Innovation Department was conceptualized as an offshoot of SELCO India and is the experimental arm of SELCO formulating innovative ideas in technology, finance and operational management and working with external networks of partners (NGOs/technical/financial/academic institutions).Currently the incubation lab is focusing on development of several innovations such as solar powered headlamps for rubber tappers, solar lighting for mid wives and flower puckers, portable lights to feed silkworms. Future design innovations include energy vendor carts, solar powered signal lights, improved cooking stoves and biomass-based dryers etc

The core of Innovation Department is to identify energy related problems, provide customized solutions based on end user needs and enhance livelihood and quality of life of people. By establishing partnerships and innovating we recognize the need to inter connect products and services and of adding value through a network to subscribe to a customized end user needs. The lab is hosted inside the premises of SDM Institute of Technology, Ujire. The rural setting gives the lab access to local customers, instant feedback, and visibility into available resources and constraints.

In addition SELCO also provides consulting to other organizations with new ideas/ technologies interested in entering rural markets. It is also focused on evaluating unexplored energy services that make sense to be introduced into the rural market and involve them into SELCO's sales channels. In addition the incubation lab also provides performance testing and customer research activities to third parties who have deployed products for rural poor.

**9. Value chain**

SELCO wants to focus on becoming a energy service provider rather than becoming a product based firm or a PV manufacturer. Therefore SELCO may not scale in this dimension.

**10.Institutional**

SELCO in the past has also lobbied to government institutions such as Reserve Bank of India to make the procedure for foreign investment from social investors abroad to firms such as SELCO less bureaucratic. Harish Hande has even lobbied Reserve Bank of India (RBI) and the National Bank for Agriculture and Rural Development (NABARD) to make their regulations and procedures easier for financing for energy services. For instance the Reserve Bank of India requires a down payment of 15% to disburse a loan, but this amount is too high for many of SELCO's customers.

SELCO is also looking to persuade government for creating solar energy portfolio in financial institutions whereby certain percentage (5 %) is under priority sector financing for solar energy financing. According to SELCO the channels of these financing could be the nationalized banks and regional rural banks. The percentage (5%) could be broken into two parts; one dedicated financing portfolio for entrepreneurs to create a network (sales and after sales service) and a dedicated financing portfolio for end users.

### 10.1.8 Conclusion

SELCO’s core competency lies in developing customized and need based solutions for meeting energy needs of poor with excellent after sales services and providing income generation activities to its customers. SELCO in order to up scale further needs to focus on developing relationships with rural banking institutions in different geographical locations in India as well as persuade policy makers to develop supportive consumer financing mechanism and reduce subsidies on fossil fuels.

## 10.2 AuroRE, Auroville, Pondicherry

### 10.2.1 Introduction

AuroRE, Auroville is a community owned enterprise based at Auroville, near Pondicherry in Tamil Nadu, India. Established over 30 years ago, Auroville is a unique hybrid of spiritual retreat, experimental multinational community and environmental research centre. Hemant Lamba founded AuroRE (Auroville Renewable Energy) in 1998 to develop, train and promote small businesses supplying solar energy to rural areas as an offshoot of Auroville Center for Scientific Research. AuroRE is a non profit organization established by the trustees of the Auroville Centre for Scientific Research in Auroville. AuroRE has been known for its integrated approach to supplying energy services, combining technical and business competence with a strong commitment to the greater use of sustainable energy..

### 10.2.2 Historical Background

A more concerted effort toward the application of renewable energy technologies in the Auroville community came in 1984 when the Centre for Scientific Research (CSR) was established. Its aim was to pioneer various sustainable technologies, including renewable energy (i.e. wind, solar and biogas), and develop these for wider use by people living in Auroville and the surrounding villages. In 1997 CSR completed its first major renewable energy project in Auroville, installing a 36.3 kWp solar PV power plant which was built in just record 29 days. After more than 6 years of trouble free operation, the solar plant continues to generate an average 130 kWh per day, supplying the Matrimandir in community of Auroville with clean reliable power.

Various small enterprises active in designing, manufacturing, integrating, installing and maintaining renewable energy systems and system components have sprung up over the years under Auroville. AUREKA , a mechanical workshop was established in 1986 which produced and installed 30 windmills in Auroville itself and another 60 in various parts of India. Auroville Energy Products (AEP) was founded in 1996 by Carsten Michelsen which focuses on high quality and efficient electronic control components for renewable energy systems such as solar charge controllers and solar hybrid controllers. AEP was one of the first solar companies on the market, and is also one of the largest with a market share of 20% in its segment and an annual production of 20000 solar system controllers. Auroville Wind Systems (AWS) was formed to specialize in power generation from wind electric generators and wind battery chargers.AWS has installed wind hybrid systems in many Indian states such as Tamil Nadu, Gujarat, Sikkim, Ladakh and West Bengal.

### 10.2.3 Upscaling mechanisms for AuroRE

**1. Vision, mission, ambition and expectations**

AuroRE’s mission is to establish platform for reliable delivery of applications and services from renewable energy sources and technologies to meet a variety of domestic, industrial and institutional requirements for rural and urban India. AuroRE aims at becoming a hub uniting end users with an array of service providers, product developers, financers and policy makers.

**2. Learning in terms of development, financing and implementation of business model**

Here learning focuses on encouraging double loop learning in terms of developing a viable business model by challenging the conventional wisdom and developing appropriate solutions by developing partnerships, finding new means of financing and undertaking experimentation. Here we describe how AuroRE over the years has developed a viable model for providing energy services.

## 1.Products and services

AuroRE 's range of products include solar home systems, PV water pumping and solar lanterns. Other products include power packs which are combo lighting systems which customize user needs and can be configured to power a wide range of appliances and devices from lights to fans to washing machines to computer. AuroRE has also developed street lights for villages, industries etc. AuroRE has identified major opportunities for setting up smaller businesses with solar lanterns. The lanterns can be a charged during the day at a central charging station typically an array of solar panels on an area of flat roof nearby The lanterns are much more reliable, provide a more constant light and are cleaner too than kerosene lamps.

## 2. Infrastructure management

AuroRE is a reliable Energy Service Provider (ESCO) acting as a system integrator and installer providing high quality renewable energy systems by combined technical, practical, financial, managmenet and even practical skills for its projects. AuroRE operates as a maintenance and service company providing proper and prompt maintenance services to end users. It operates as system integrator and develops an optimized system by gathering components for solar energy products. In the process it has interacted with various product manufacturers, lease companies, subsidy providers and end users. Thus AuroRE has played the role of intermediatery in the process

AuroRE has worked alongside with quality manufacturers such a TATA BP Solar and BHEL for sourcing components for installations. In the past AURORE did two massive projects related to solar home systems in Laddakh and solar water pumps in Punjab. Many times AuroRE has also bought from suppliers on bulk thus reducing costs while maintaining optimal product and component quality. Many times companies have even subcontracted and paid AuroRE to carry out installation, local training, capacity building and maintenance tasks. AuroRE also feels that much of the PV market in India has been subsidized in the past and by discouraging a culture of enterprise and ownership. Such subsidies have sometimes created problems rather than fostered the successful spread of solar energy technologies. Since its inception AuroRE has focused on setting up a viable businesses providing PV on a non subsidized basis.

## 3. Customer interface

AuroRE has concentrated on making renewable energy technologies , in particular solar PV and solar thermal accessible and affordable for as many people as possible in rural as well as urban environments. AuroRE coordinates the installation process from surveying of all the sites to arranging for transportation of materials to subsequently installing the systems. AuroRE also looks at overall programme management, quality control and on site inspections. It has also developed a stringent quality monitoring system of procured components and assembled renewable energy products.

AuroRE also trains local people via demonstrations and written instructions in local languages as well as English about solar energy. For the end users AuroRE has also set up credit and soft loans for at both microcredit and institutional levels.AuroRE in the past has co coordinated access to government subsidies and worked with financial institutions to draw up appropriate financial mechanisms for poor people to buy solar energy products at affordable prices and make best use of government subsidies by MNRE, IREDA and other government agencies. AuroRE has developed mechanism in which users pay an initial charge which is about 10% of the system cost, and then a rental fee of per month which is collected by village level workers. If the rent is not paid the system is eventually taken away from the defaulting household. It has also set up field offices in the places for repair of faulty equipments by also setting up village based funds which can be used for systems maintenance and battery replacement. AuroRE also provides post installation maintenance and services along with managerial and technical training for responsible technicians and end users. AuroRE has also reached end users and small traders by supporting small entrepreneurs who hire out and maintain solar lanterns.

**4. Financial aspects**

AuroRE'S main source of revenue comes from its project services. AuroRE has not taken in any external investments due to the regulations of the Auroville community of which it is a part. However the PV work of AuroRE has been running on a commercial basis. A portion of the profits made through PV installations and services goes back to the Auroville trust of which AuroRE is a part of. AuroRE thus runs on a no profit no loss basis. AuroRE has however relied on external financing agencies for financing mechanisms for customers through government schemes from IREDA. AuroRE is also looking on creating system by which it can sell carbon offsets generated by some of its projects to subsidies retail prices for its customers.

**5. Fit of the business model**

Through AuroRE's model has been successful but also faces problems due to rapid fluctuations in prices for various solar energy components .However AURORE has also managed to resolve the issues to some extent by forming long term partnerships with reliable suppliers such as BHEL and TATA BP Solar.

### 10.2.4 Human resources and partnerships

AuroRE has a small core team of individuals from diverse backgrounds. The central team is made up of engineers, environmentalists, planners, designers, administrators, computer specialists and support staff. AuroRE is headed by Hemant Lamba who has experience in financing PV projects, with some other important people like Kavit Kumar who looks at financial administration matters and Hemant Shekhar who works at various research projects. Jos Van Den Akker who is a PV technology specialist also worked for AuroRE but some time ago. Most of the people working in AuroRE work on a very small salary due to the regulations of the Auroville community. Most of the work of AuroRE is done voluntarily by the people working officially in AuroRE and by volunteers who come from all over the world.

AuroRE has always looked for nurturing alliances and partnerships as they can reach far with the help of the alliances. AuroRE is looking to further promote renewable energy technologies by cultivating extended associations with NGOs, government bodies, citizens groups as well as industry and corporate. In terms of technology partners it has developed relationships with TATA BP Solar, SELCO and BHEL. Over the years AuroRE has developed relationships with NGO's such as Maitri based in Pune for a solar water pumping project, ECO Sphere Spiti based in Spiti Valley in Himachal Pradesh, Gram Vikas based in Orissa, Sahjeevan an NGO and with Sun Min, an enterprise in Chennai for promoting small entrepreneurs for hiring and maintaining solar lanterns.

### 10.2.5 Gaining legitimacy

AuroRE has gained legitimacy by becoming a reliable energy service provider and financial intermediatery and also developing strong linkages with government bodies such as MNRE and IREDA. AuroRE was awarded in 1997 by IREDA for being the best NGO in the renewable energy sector. In 2001 it received PV SEC award for its commitment to a use of renewable energy sources by supporting de centralized local economies. In 2003 it is also received an appreciation award from TATA BP Solar as a respectful client.Dr Hermann Scheer also awarded SOLAR INDIA award in 2004 to AuroRE for its contribution to sustainable energy.AURORE also received the Ashden awards for sustainable energy in 2004.It also received an appreciation certificate from World Bank in the development market place competition. AuroRE is also a certifying authority for carbon emission reduction projects with certifying groups like Carbon Neutral of UK.Therefore all these awards and certifications have been relevant for AuroRE to gain legitimacy.

**10.2.6 Barriers to upscaling**

AuroRE also faces several barriers out of which the most critical barriers are lack of finance and human resources. Due to the specific regulations from Auroville community AuroRE cannot raise finance from external agencies. AuroRE is currently run by extremely dedicated people at very low salaries and also lacks human resources which limits upscaling.

**10.2.7 Upscaling performance in different dimensions**

**1. Quantitative**

AuroRE has been successful in delivering affordable, reliable renewable energy products and services which benefit more than 80000 Indians. AuroRE’s projects include installing 1025 solar water pump sets to farmers in 11 Indian states such as Punjab, providing solar lanterns to street hawkers in Chennai and coordinating a rural electrification project in Ladakh using 8700 solar home kits and 6000 lanterns.

**2. Net impact**

AuroRE has impacted the life of many people with benefits specially to farmers in terms of reliability; fossil fuel saving and quietness in operation by replacing diesel pumps with solar pumps. Other benefits include providing opportunities for better livelihood and reducing harmful kerosene emissions etc.

**3. Organizational**

AuroRE is focusing on becoming a knowledge service provider for energy services with core expertise in energy service provider, consultancy in renewable energy technologies, programme and project management and energy efficient architecture. It is also becoming a trainer in solar energy technologies by providing quality training from how devices and application work to installation to post installation services to students and technicians planning a career in renewable energy through workshops, demonstrations and site visits. AuroRE through its experience is also offering its services to European companies in looking to certify and carry filed inspections on renewable energy projects and carbon emission reduction projects and programmes for their Indian clients. In addition AuroRE is developing mission Tejas which is a facilitator and a platform of exchange an development for solar energy technologies by bringing together lighting designers, product manufacturers, NGOs, administrative bodies, financial institutions and corporate/industrial R&D.

**4. Geographical**

AuroRE has been successful in delivering affordable, reliable renewable energy products and services across 12 Indian states such as Andaman and Nicobar island, Tamil Nadu, Puducherry, Karnataka, Kerela, Orissa, Jammu and Kashmir and Gujarat.

**5.Depth**

AuroRE is planning to reach increasingly poorer segments of the population by making use of government subsidies from MNRE and IREDA with a way that does not distort the market for solar energy. It is also planning to reach very poor segments by starting lantern renting schemes where people like street hawkers, workers can rent lanterns from entrepreneurs for an evening and then return them back for charging.

**6. Functional**

AuroRE is also developing new products such as LED/CFL based home lighting lanterns  as well as solar manual powered reverse osmosis systems to purify drinking water. AuroRE is also working on new products such as improved solar rice cooker, solar lantern and solar home lighting kits. It is also looking for providing new renewable energy services.

**7. Replication**

AuroRE is also focused on creating solar entrepreneurs which can become financially sustainable through different ways such as hiring out solar lanterns to market traders or supplying and installing solar water pumps to farms.AuroRE is aiming to set up a whole chain of local energy entrepreneurs by effectively providing them with managerial, technical and financial back up. AuroRE  is also training several people and developing a network of sustainable enterprises among economically deprived communities including training at least 250 people in installation and maintenance of PV solar systems

**8.Innovation**

AuroRE has been engaged in research and development of various energy technologies covering a broad field of applications from energy devices to agricultural dryers and transportation systems, wind pumps, solar bowl concentrator for process heat, ferrocement based bio gas, small hydro installations, building integrated photovoltaic's, electronics for solar photovoltaic systems, AV 55 AND AV 45 wind pumps, solar PV pumps, solar home lighting systems, solar PV power packs, solar lanterns, small wind battery chargers and small hydro systems up to 25 K . AuroRE has also been engaged in development and testing of PV modules and even patented some designs.

**9. Value chain**

Since AuroRE is an energy service provider and also lacks capital and human resources to expand AURORE is not likely to scale in terms of becoming a PV manufacturer.

**10. Institutional**

AuroRE has developed good relationships with government bodies for renewable energy such as MNRE and IREDA.In the past AuroRE has also advised and done assignments for government bodies. In March 2010 Dr. Farooq Abdullah, the Union minister for new and renewable energy visited AuroRE and discussed how solar energy in India can be up scaled. AURORE has also advised government to reduce huge kerosene subsidies as they alleviate energy poverty. However all these efforts have not resulted in any kind of institutional upscaling.

**10.2.8 Conclusion**

AuroRE's core competency lies in installation and financing of various solar energy technologies and linkages with government bodies with government bodies such as MNRE and IREDA. AuroRE needs to focus on building a strong human resource base in order to up scale in future.

### 10.3 THRIVE Energy Technologies, Hyderabad

### 10.3.1 Introduction

THRIVE (Volunteers for Rural Health and Information Technology) is a non profit organization which was founded in 2001 under the Indian Societies Act for developing rural and unprivileged communities in the areas of health, communication, rural lighting and water lifting by Dr Ranganayakulu Bodavala, who is a Harvard alumnus as well as a public health specialist. The key areas for THRIVE include home lighting, ICT, education and health using advanced and innovative technologies. THRIVE was initially founded with focus on rural health and information technology but started lighting business in 2002. THRIVE has a strong belief in action-based rural research projects in ICT, water conservation, energy conservation, ecology development, rural connectivity, and livelihood training. THRIVE operates out of an office based in Hyderabad and also has a campus in Chintapally, Andhra Pradesh. In March 2007 Mr. Ranga started a profit venture Thrive energy technologies pvt ltd for making the operations more financially sustainable and also for performing the functions of the NGO separately.

THRIVE focused on developing LED technologies as solar lanterns previously disseminated by bodies such as MNRE in India failed to meet the lighting needs of a large number of people. Thrive over the years has developed uniquely designed LED home light for rural people and also takes care for the installation and maintenance services. Thrive has more than six years of field experience in LED based lighting and has also developed the concept of energy kiosk which is based on employment linkages and maintenance of supply chain for LED lighting. THRIVE over the years has also expanded its knowledge of LED lighting to various NGO's,institutions and rural entrepreneurs and helped a large number of disadvantaged sections of society such as fishermen, weavers, fruit gatherers, dairy farmers, and street vendors etc.

### 10.3.2 Historical Background

THRIVE started its work in LED Lighting in a small way back in 2001 when the concept of using LEDs as an alternative to costly and inefficient incandescent light bulbs and not so efficient CFLs was yet to be realized in India. THRIVE implemented its first project in LED lighting technology in a remote tribal habitation called Choututla in Nalagonda district of Andhra Pradesh. During the project 33 houses were each provided with 3 LED light bulbs each, which were powered by a common apparatus consisting of a 36w Solar panel mounted on one rooftop, a 40amp 12V lead acid battery, and a charge controller.

Dr. Bodavala had knowledge of rural markets and energy spending habits of people but THRIVE also monitored the usage of lighting over a period of 6 months. After studying the usage patterns, effectiveness of LED lights. THRIVE decided to go ahead with the model in other locations such as Nallamala forest range, one of the largest forest range in Andhra Pradesh. THRIVE initially also targeted the consumers through word of mouth marketing.

By February 2003 THRIVE had its first lightning model with the design being like a light bulb consisting of LED lights which were installed on a wall and connected to a solar panel. The first lanterns were installed in Chintapally and Lambada village. THRIVE also started looking for other communities for starting larger pilot project with the goal to test the lights and their applicability on a larger scale. THRIVE conducted several projects from 2003 till 2005 and five different lantern models were tested, implemented and improved with feedback.Initially THRIVE gave lights and components free of charge with operation and maintenance being done by THRIVE too, but soon THRIVE started to see problems such as burglary, issue of lights and lack of accountability. THRIVE also found that only 2 out of 22 projects which it started were operating as the village headman in them took the responsibility of maintaining the systems. It also realized that financial ownership and incentives were necessary for financial sustainability of its operations.

In early 2005 THRIVE expanded into tribal areas of Orissa and Chatiisgarh where it linked with Anukaran, local NGO based in Rayagad, Orissa .THRIVE and Anukuran worked in ten communities together where the community members were made responsible for all the capital costs and operating costs. Solar powered charging stations were also built within walking distance of communities and volunteer were chosen from the community whose responsibility was to collect the lanterns for charging. For building technological capacity and capabilities five youth were also trained through a six month intensive training programme in electronics, LED operation, welding and fabrication. Their main work was to resolve all operation and maintenance issues in the communities. The technicians were put through 3 to 6 months intensive electronics training to monitor the charging station and fix the problematic lanterns. They were also required to report community usages and report abnormalities to Anukaran.Expended batteries, lanterns and lantern parts were also sent to Anukaran for recycling. The technician salary came from monthly service charge and grant from development market place award.

THRIVE also developed new lantern model in 2006 which had a reduced battery size and capacity, cost, weight and size. THRIVE also started using existing grid power for charging in some places since it solar charging stations were not highly cost competitive. A circuit design expert was also hired to increase the efficiency of LED lantern. The new circuit had fewer, brighter LED's which increased the overall luminousity but also decreased the price and even increased battery life by 30 %. Further the circuit and batteries and the back panel of the lantern incorporated fewer screws, electronics and wires were padded and colored for safety reasons

THRIVE found that solar powered LED lighting met the needs of the people in terms of lighting for long period of time but the major problem was that the lighting was unidirectional and costly. In order to address the problem of unidirectional lighting component of LED THRIVE also started a pilot project to understand user adoptability and tweak his model based on their reactions. In order to resolve these issues Dr Bodavala began buying from manufacturers which had most competitive prices and also worked on improving the technical efficiency of the LED's, circuits and batteries. Highly motivated youth from surrounding communities were also recruited and trained in design and development of solar based LED lighting.

In the past THRIVE also faced problems due to bottlenecks in the production process since the different aspects such as manufacturing, whole sailing and retailing were not co ordinated well. THRIVE also faced troubles due to lack of financial sustainability as it was highly dependent on donor money from World Bank, shortage of human resources and lack of suitable partners.

### 10.3.3 Upscaling mechanisms for THRIVE

#### 1. Vision, mission, ambition and expectations

THRIVE's mission is to provide clean and reliable lighting solutions to billions of people around the world. THRIVE believes in action research and wishes to improve the living conditions of people by carrying out projects in RURAL ICT, water-conservation, energy conservation, ecology development, rural connectivity and livelihood training.

#### 2. Learning in terms of development, financing and implementation of business model

Here learning focuses on encouraging double loop learning in terms of developing a viable business model by challenging the conventional wisdom such as poor cannot afford sustainable energy technologies, setting up partnerships, undertaking learning and experimentation and being financially sustainable. Here we also describe how SELCO developed its learning strategies for meeting the energy needs of the poor.

**1. Products and services**

THRIVE has several range of products like LED portable home light, solar LED home lighting systems for large homes, low cost study light for children in villages, multi mobile charging systems for villages located far off , solar panels of different watts, solar panel based power back up systems and solar institutional lighting for schools, hospitals, banks etc. THRIVE also manufacturers its own solar panels between range of 1 MW and 200 MW and 14 types of LED lighting products for rural as well as urban applications. Some special products from THRIVE include Accendo home light which is solar home light with three modes of lighting which with a single charge can last up to full 30 hours in bright mode; Accendo mini light is the smaller version of home light which can last up to 12 hours with a single charge. In addition THRIVE also offers consultancy services in energy efficiency and development of different solid state lighting technologies.

**2. Infrastructure management**

For development of its products i.e. lanterns THRIVE imports microchips from U.S.A, batteries from China, LED lights from Japan. These components are then assembled in manufacturing units based in Hyderabad. Assembled circuit boards are then combined with LED's and then send to assembly factory. The collected components are then combined with locally made chasis and then assembled by hand.
With the intention of localizing the production and servicing of its lighting products, THRIVE Energy Technologies has also set up assembly line plants in other parts of the world like Nairobi and Ranchi, Jais in Raiberily district of UP.

**3. Customer interface**

THRIVE's route to market and customers has been through NGO's, organizations like United Nations, World Bank etc. Through this route an NGO or a government/semi government agency usually contacts THRIVE for lighting solutions in a village. Generally the NGO also has an office in relative proximity to the village and some field volunteers in the village. From each village the NGO has a volunteer and co ordinator for programmes in that village. THRIVE also prepares good GIS map of the area to be provided with lighting to understand the local electricity supply and usage patterns. It then installs some demonstration lighting in the village either using its own funds or some initial funding from the NGO. This helps the community, NGO and other stakeholders to take part in the project. It then organizes training using video CD's, posters, instruction book lists for the NGO and the end users and explains the stages to be carried out for the implementation of the project. THRIVE also focuses on customer service by training local people as technicians. It also makes sure that users are also informed of the location of nearest technicians as most of the users do not have access to information and communication technologies. The NGO is also required to borrow the funds at commercial rate and repay within 5 years and is granted the money or it is lent on an interest free scenario. The NGO then expects the household to pay a certain amount of money as upfront payment and the rest as a monthly payment for 5 years which covers cost for light, maintenance and battery.

In addition THRIVE has also established charging stations each of them can serve up to 10 villages depending upon the proximity of the station to the villages. The NGO also collects the advance deposit from the households at an agreed rate. Every 10 days rural volunteers organize charging of batteries at the charging station either through gird power or through solar charging station).Charging stations generally keep 3-4 spare fully charged batteries as well as lights for maintenance. In addition THRIVE has also established district maintenance units which carry spare display PCB's and control units in case there are some major maintenance issues. Monthly rental is also collected by rural volunteer and paid to the NGO.The share of the volunteer is distributed accordingly. The profits earned by the NGO can be re invested into the villages or use to reduce the upfront money for many villagers.

THRIVE has also developed unique concept of energy kiosks in villages in which each kiosk can serve from 100 to 500 or more lights. Members deposit the light in the morning and collect in the evening once in a week on a fixed week day. Each member is allocated a particular day of week for charging. Users pay up to INR 20 a month for good full charge and maintenance of the light. For every 200 to 250 installed LED Home Lights THRIVE also trains an entrepreneur (woman or man) who collects a small fee (Rs 10 for each charge a minimum of twice to a maximum of thrice a month, depending on the use) for charging the LED Home Lights, either through grid power or at a solar charging station where there is no grid power available. The village entrepreneur can earn a monthly income of INR 2000 to INR 4000 based on the number of LED Home Lights he/she maintains and services.

Further regarding financing mechanism for customers THRIVE has developed customized financing mechanism to help the poor to acquire lighting solutions by working with micro finance organizations, women groups, rural banks, NABARD, SIDBI and a host of international NGO's. THRIVE is now also partnering with micro finance agencies like SKS microfinance and Basix, Chanura, Ori, Michalemia,VVD, IDPMS which have a large customer base already to develop financing mechanisms for people to buy LED lanterns.

**4. Financial aspects**

From being a small size NGO THRIVE now has grown into a full fledged commercial enterprise. THRIVE's main source of revenue come from sales of its different products. THRIVE initially survived on grants from World Bank and other international agencies. It also won the World Bank Development Market place award in 2006 through which it was able to sustain its activities. THRIVE also has a commercial enterprise running alongside which is THRIVE energy technologies pvt ltd which also funds many of its development activities.

Lately THRIVE has started looking into gaining carbon credits and developing CER (Certified emission reductions) from its LED lighting projects. It has also received approval from Global environment facility(GEF) for its unique LED light programme in India which could generate around USD 7 per annum of carbon credits in gold standards which are endorsed by over 44 non governmental organizations worldwide. THRIVE is also now developing PDD for the carbon emission reductions by using the LED based lights and eliminating the wick lamps. With this mechanism of financing THRIVE will be able to supply lights to millions of people. In addition THRIVE is also relying on corporate social responsibility programmes, government livelihood improvement projects and its own revenues to generate revenues for more projects.

**5. Fit of the business model**

Although THRIVE's model has seen successful but it faces problems due to lack of research and development and large scale manufacturing of LED technology in India. Thus THRIVE is dependent on supplies of different components from firms in USA, China and Japan. THRIVE also faces problems due to of intellectual property issues as the lantern designs by THRIVE have been copied and imitated by other manufacturers and sold as cheap alternatives. Rapidly changing nature of LED technology with fluctuations in LED prices, quality and market conditions make it difficult for THRIVE to apply for patents to tackle the intellectual property issues.

### 10.3.4 Human resources and partnerships

THRIVE is headed by Dr Ranganayakulu Bodavala along with Mr Sreekamal Bandopadhyaya as project manager and Mr Satish Somepalli as the director of finance. It has range of experts in areas such as geology, GIS, rural technology, IT, rural kiosks and networking and marketing. THRIVE has around 94 employees in production in manufacturing and production and 142 employees in field operations with a strong team of engineers and technicians. Most of the THRIVE's employees have rich experience in different areas such as public health, environment management, renewable energy, marketing and entrepreneur development.

THRIVE has been working with a large number of organizations such as Gram Vikas, Anukaran in Orissa, Kisan Mahasabha in Jharkhand, Malghat Mitra, Vigyan ashram in Maharashtra, SEWA in Gujarat, CCN in Visakhapatnam, ESAF, Ashakiran, SSvetcha, Ashram Pabal Maharashtra, Kisan Mahasabha Ranchi .Other linkages include Earth institute Kenya, Lighting project Kenya, SURF Rwanda, S3IDF Bangalore and Hyderabad, Technology for People Koorg, IDPM Bangalore .THRIVE is now working with the Government of Andhra Pradesh (social forestry department) on a rural poverty alleviation project. In addition THRIVE has focused on strong research and development and is in constant touch with largest LED manufacturers such as Kyocera, Citizen, Edision, Opto for latest developments in PV technology.

### 10.3.5 Gaining legitimacy

THRIVE has gained legitimacy by developing low cost LED lighting solutions and partnering with large number of international and national level organizations. It has also become a trusted partner for organizations such as World Bank, UNIDO and other global organizations. THRIVE also won the World Bank development market place award in 2006, Lighting Africa project of World Bank in 2008 and Lighting Tanzania award in 2009.All the recognitions have helped THRIVE in gaining legitimacy.

### 10.3.6 Barriers to upscaling

THRIVE has found problems with respect to finding good local manufacturers for its local assembly operations. Lack of infrastructure and adequate human resources has also created problems for THRIVE. Other barriers are lack of finance from banks for expansion and high VAT(Value Added Tax) on solar energy products.

### 10.3.7 Upscaling performance in different dimensions

#### 1. Quantitative

THRIVE's long term mission is to disseminate 100 million lights all over the world .Till now it has benefitted approximately 160000 people and most of the people benefitted are poor and tribal people.

#### 2. Net impact

LED lights by THRIVE have been able to improve productivity and lifestyle of people by extending their work hours. THRIVE has also benefitted many small scale entrepreneurs by providing employment opportunities to them. The LED lights by THRIVE have also reduced carbon emissions over the years from kerosene and diseases such as malaria. In this respect THRIVE has also been actively involved in a result oriented activity to measure its impact using indicators like number of households providing lighting, number of youth trained as entrepreneurs and percentage increase in entrepreneurs income.

**3.Organizational**

THRIVE has generated revenues of around USD 2 million. THRIVE is also developing a renewable energy center outside Hyderabad for training and demonstration projects in renewable energy. It has plans to start new rural programs for rural water treatment, rural electrification, rural banks and rural village outlets. THRIVE also has plans to enter into solar power generation business in line with the National Solar Mission of Government of India. In addition THRIVE is also helping many corporate organizations to implement Corporate Social Responsibilities (CSR) programmes for implementing LED lighting programmes.

**4. Geographical**

THRIVE has had a wide geographical reach due to the support from various groups and organizations around the world. At present THRIVE is strongly established in Indian states like Orissa, Andhra Pradesh, Jharkhand, Bihar, Maharashtra, Manipur and nations such as Afghanistan, Cambodia, Bangladesh, Ethiopia and Kenya.

**5. Depth**

THRIVE is also channeling its resources to reduce the cost of LED lights and to reach deep tribal areas in Orissa,Nallamalla forest range in Andhra Pradesh , geographically distant regions in India such as Manipur where poor people have been neglected in terms of meeting their lighting needs. THRIVE has also taken initiatives in the Lighting Africa project where it is trying to reach increasingly poor segments. In addition THRIVE is also trying to reduce cost of LED based lights by using new means of financing such as carbon finance where poor people can afford the lighting solutions at very low costs.

**6.Functional**

THRIVE has also introduced other forms of lights that are useful to the villages like street lights, task lights etc. at a very economical rates using state of art LEDs. Thrive is also focusing on scaling its products and services and is looking for a major share in niche markets such as street lighting, hoarding and institutional lighting.

**7.Replication**

THRIVE is encouraging village entrepreneurship by promoting solar light entrepreneurs everywhere in the world by providing line of support, product and training in India. THRIVE is creating employment opportunities for many rural people in terms of maintaining and charging LED lights. This is also helping people to increase their income serve their communities. THRIVE is proposing alternative energy kiosks in villages in which users can walk and get light charges for a token fee and enjoy continued service and maintenance of light which are run by local youth with minimum education like matriculation and basic training in electronics and mobile phone usage.

THRIVE is also looking forward for development of local entrepreneurs in LED based home lighting with the intention to create micro, small and medium energy service enterprises for manufacturing, selling and servicing LED lamps in Kenya. The Kenyan Industrial Research and Development Institute is collaborating with THRIVE and acting as a nodal agency for technology transfer and entrepreneur incubation. The project aims to develop about 10 entrepreneurs who can install lights in as many as 25000 homes with the help of small local businesses. In the process THRIVE will build the capacity of KIRDI staff through training, study tours and establishment of a pilot assembly plant complete with laboratory equipment.

**8. Innovation**

THRIVE is focusing on research and development due to continuous evolving nature of LED technology and competition from Indian traders who import cheap lights from China not specifically designed for users. Therefore THRIVE is doing continuous research and development for providing high quality products at affordable prices.

**9. Value chain**

THRIVE has a fully fledged manufacturing capacity for making solar panels of various types with an installed capacity of 15 Mw and is also focusing on moving up the PV value chain.

**10. Institutional**

Dr. Ranga Bodavala has also suggested governments both in India and other countries in Asia and Arica to reduce kerosene subsidies and focus on providing low cost, highly reliable LED lights. THRIVE is trying to persuade the Indian government to reduce high VAT taxes on solar energy products.

### 10.3.8 Conclusion

In order to upscale further THRIVE should focus on developing its core competency i.e. development of different LED based lighting solutions and action research projects for poor communities in different regions of the world. In addition THRIVE should also focus on persuading policy makers for supportive regulations for development of solar energy in India.

## 10.4 NEST, Hyderabad

### 10.4.1 Introduction

NEST( Noble Solar energy Technologies) is a private company based in Hyderabad, India, which was set up by Mr D T Barki in 1998 to develop a very small solar lantern, the 'Aishwarya' as a safe substitute for the kerosene wick lamp. NEST was established as a profit making business with a very clear social focus which is also evident in the day to day operations of NEST. NEST aims to become the leading supplier in its chosen markets i.e. solar energy products and services and acknowledges that it can achieve and maintain this goal through the highest level of commitment to providing the best quality and the best price.

### 10.4.2 Historical background

Mr D T Barki had previously followed a successful career in the PV industry in India but having seen a baby die in a house fire caused by a kerosene lamp when he was a child, he decided to use his knowledge and expertise to build solar lantern and eliminate kerosene lamps. From his experience gained before at Photon which manufacturerd and supplied lanterns to government bodies, Mr D T Barki found that most lamps distributed in government programmes were over designed. According to him and a new product could be built which can serve the requirements of poor people at much lower costs. Mr DT Barki felt that the Indian PV industry had concentrated more on commercial projects and ignored needs of people living in rural areas. He could see potential of providing affordable solar energy based lighting and thus set up NEST in 1998. The aim was to produce clean, reliable and affordable solar lighting with lamps designed in such a way that they are robust as well as portable and can be used easily by children, women, farmers or anyone.

From 1998 to 2001 Mr Barki worked on a solar energy lantern. Initially he explored various possibilities including importing some components and indigenously manufacturing others. Finally Mr Barki decided to manufacture solar panels in India, procure batteries and electronics from a company based in Singapore and collaborate with a local plastics manufacturer to build the housing for the lamp. He also extensively worked with OSRAM India to develop a special 3 Watt CFL that did not exist in the market before. Finally he was able to develop a solar lantern i.e. 'Aishwarya' solar lamp. The most significant aspect was that the price of solar lantern came down to less than one third from the pre subsidy days and around half of the post subsidy prices supplied by the government agencies.

When the Government pulled back subsidies on Solar Lanterns in 2003 the attractiveness of the product increased even more. After developing the "Aishwarya solar lamp" Barki created a comprehensive business lamp based on his extensive lamp. He also brought in Uttam Reddy from the previous company he worked PESL to launch a new company called NEST (Noble Energy Systems Ltd) and also offered Reddy a 25 % stake in return for his financial and infrastructural support. The lantern design and manufacturing systems were developed over a period of three years and commercial production started in 2001. During the period 2001-2003 NEST started servicing an initial order of 100 solar lanterns which was followed many small orders thereafter.Mr. Barki focused his attention on cost reduction in procurement of components. He also used solar cells which were electrically functional but aesthetically unappealing with objective of recycling and reusing them. Further Mr. Barki also established solar manufacturing plant near Bangalore after establishing a makeshift assembling facility at Hyderabad.

Mr. Barki was also interested in aggressively promoting the solar lantern and also appointed several dealers across the country in short span of time. Most of his dealers were initially located in Indian states of Andhra Pradesh, Karnataka and some regions of Maharashtra. He supplied the dealers with the product on lucrative terms leaving 25% to 30% dealer margins with a credit period of one month. These dealers were selling the lanterns as well as other consumer durables. A typical dealer also had salesman who would cover 150 km journey everyday passing through adjoining villages. However his criteria of selecting dealers were not very stringent. Most of his dealers were located small towns in India which were also easily connected to villages.

However this strategy proved problematic. In the urgency to upscale and expand Mr. Barki did not chose the dealers wisely. He struggled to get his money back from the dealers for his products sold on credit. Despite the financial troubles NEST managed to establish a strong reputation in the market for “Aishwarya” solar lamp and gained market visibility. Later “Exide” one of India’s largest battery manufacturer also approached NEST for a technical collaboration and for a partnership in which NEST was supposed to manufacture and supply solar lanterns and Exide was to supply the batteries under their own brand name. Through this tie up NEST managed to receive two orders of 10000 lanterns each which effectively pulled out NEST out of the financial mess to some extent.

Mr. Barki in order to develop market for NEST offered micro credit scheme through the dealers so that poor people could buy solar lantern at an EMI of INR 100 per month which was arrived at by studying the costs poor people were paying for kerosene usage. NEST tried to offer value proposition with a lantern with a minimum warranty of 10 years for solar modules and one year for other replacable parts. NEST also introduced several other categories of solar based products such as solar powered fans etc. It also faced bottlenecks due to global capacity of solar cells which are used to manufacturer solar modules and panels.Barki through his research found that quartz can be also used instead of silicon. Mr.Barki found quartz reserves in the state of Andhra Pradesh and got into the business of mining and exporting the ore for Silica extraction. Barki not only benefited from selling the ore, he also managed to obtain discounts from silicon wafer suppliers for raw material needed to fabricate his solar modules. This helped him to further reduce costs and increase profitability. However the mining business also faced losses in 2008-2009 but has picked up lately.

### 10.4.3 Upscaling mechanisms for NEST

#### 1.Vision, mission, ambition and expectations

NEST's long term vision is to provide innovative lighting solutions to really needy people world over. Its mission is to apply its scientific, technical and management expertise to all aspects of the challenge to implement sustainable energy services globally by providing highest quality, most reliable, and affordable solar photovoltaic systems for the benefit of people and the planet. NEST also aims at emerging as world’s serious manufacturing company in the supply chain of solar grade starting from high purity Silica/Quartz.

#### 2. Learning in terms of development, financing and implementation of business model

Here learning focuses on encouraging double loop learning in terms of developing a viable business model by challenging the conventional wisdom such as poor cannot afford sustainable energy technologies, setting up partnerships, undertaking learning and experimentation, and being financially sustainable. Here we also describe how NEST has developed its learning strategies for meeting the energy needs of the poor.

#### 1. Products and services

NEST has pioneered in the design and development of AISHWARYA, an affordable solar mini lamp for the rural households across the world. The lantern is similar in size to kerosene lamp which uses a 3 W high-efficiency compact fluorescent lamp (CFLs) producing 60 lumens of light, with a 3 Wp detachable

PV module. NEST's lanterns have minimum 4 hrs of operation, 360 degree uniform and soothing light; extended battery life and 5 years performance guarantee. NEST has other product portfolios in terms of different solar lanterns, solar home lighting systems and solar street light systems. It also manufactures different range of crystalline silicon solar modules. NEST is also working on developing new versions of AISHWARYA lamp named AISHWARYASUN-KIRAN 360 and AISHWARYA WOW.

**2. Infrastructure management**

NEST's core competence lies in design, development of new and innovative products. It has designed solar lanterns in such a way which allows easy replacement of key parts rather than repair. NEST has established manufacturing facilities at Hyderabad and Bangalore in which the solar module and system assembly facilities are characterized by efficient, effective and most economical infrastructure. NEST makes the polycrystalline PV modules at its own factory in Bangalore. The plant has a capacity of 20 KWatts/ month which translates to about 6500 units of 3Watt panels. The plant is capable of running three shift operations employing 12 people in every shift including a manager and a supervisor. About 100,000 solar panels can be produced each year at the NEST factory. NEST designs its own electronic controllers, and purchase the components for them to ensure quality, but outsource the manufacture to a small electronics business in Hyderabad. Manufacture of the plastic housing has been outsourced to another small business unit near Hyderabad.

The lanterns are assembled at the NEST workshop in Secunderabad. At the NEST factory in Begumpet, Hyderabad, the first step of the manufacturing process is putting the housing together. Then the fluorescent bulb is inserted and enclosed in a plastic casing. The battery is fixed to the circuit board and connected to the bulb. The solar panels consist of small solar cells suitable for 3 peak watts output, enough to power one mini-lamp. These are tested for the right voltage, tabbed together with copper wire and sandwiched between high transmission glass and polymer sheets. These sheets are laminated and cured in an oven at 150°C. The edges are then trimmed, taped and the panels fixed. The panels are then shipped to Hyderabad and packed along with solar lamp for distribution. To ensure the longevity of the product the battery is guaranteed for three years and its solar panel for ten.

**3. Customer interface**

NEST specifically has intended its product to be sold as an unsubsidised, commercial product NEST has developed Aishwarya solar lantern which costs around INR 2300 for rich villagers whose income is around USD 5 per day, flashlights intelizon costing around INR 1500 for middle income people with income around USD 2 per day and daily rental schemes of Aishwarya Wow which costs around INR 5 per day for low income people earning less than 1 USD per day.

In order to reach the customers NEST has established a network of dealers based in small towns all over India. Dealers are independent businesses, sometimes selling other goods or services as well as lanterns, and are provided with training, stock, spare parts and support by the NEST head office. Each dealer recruits a number of sub dealers who work on commission at village level and who have close links with the community. Dealerships vary in size and typically sell between 500 and 1000 lanterns per year. NEST has already developed a network in over 3000 villages across 17 districts in Andhra Pradesh and this network is also present in other Indian states such as Karnataka, Maharashtra and Madhya Pradesh.

NEST also realized that most customers cannot afford the purchase price of lanterns so NEST decided to introduce financial mechanisms for people to buy them on credit from the dealers. Typically customers are asked to pay around INR 200 per month for 8 months or INR 100 for 16 months. NEST sometimes reduced its own profit in order to allow the dealers to give free credit. The sub dealers collect the payments from their customers as they know the people well. They have been able to collect money from people who do not have a formal address. Many times customers had to extend their repayment period, but the overall track record of repayment is very good with only about 3-4% defaulting on payments. According to NEST the dealership network with the detailed local knowledge it provides has been crucial in enabling the lanterns to be sold successfully in really remote areas. The network has also provided an effective route for sales and also for training, replacement parts, after sales service and recycling of batteries and other electronic stuff. NEST have been able to motivate their dealers to follow their approach of providing a high quality product and service to poor people, while at the same time allowing the dealers to function as independent businesses. NEST has also made sure that the sub dealers have to make sure that each user knows that they must recharge their lantern every day otherwise it will not provide the intended 3 to 4 hours of light each evening. Sub dealers in addition also carry a few spare controllers, batteries and CFL's which can be changed easily during the one year guarantee period in case users face any problems.

Apart from this distribution mechanism NEST's solar lanterns have also been bought and distributed by NGO's in social programmes many times. NEST has also given away many lanterns in promotions and high profile events such as prizes to poor students etc. NEST has provided PV street lights for some government programmes, and have also donated them to some of the slum communities. Apart from it NEST has also used corporate firms under their social responsibility schemes, on resident villagers (successful businessman and industrialists) with roots in villages, dealers, landlords in villages for distribution of its different products.

**4. Financial aspects**

NEST's main source of revenues comes from sales of its solar energy products and services. NEST has secured finance on a straight commercial basis, through private investors and banks. A loan from Winrock International helped it in the rapid expansion of the business in 2004. NEST has been financed by innovative means in the form of other businesses such as silica mining and revenues from supplying high purity quartz to polysilicon and silicon companies such as Msetek, Japan; Becancour Silicon Inc.

**5. Fit of the business model**

NEST over the years has developed a viable model but it is also faces problems such as  high distribution costs in reaching the people. A large percentage of the market price of the lanterns by NEST is used up for distribution costs. In this respect NEST has been able to leverage distribution channels of corporate partners and international organizations but still high distribution costs in terms of reaching people is a challenge. NEST is also in multiple stages of the PV value chain i.e. supplying polysilicon as well as manufacturing and distribution of lanterns as well. Therefore being in multiple parts of value chain also creates problems for NEST.

### 10.4.4 Human resources and partnerships

NEST is managed by Mr D. T. Barki who has extensive knowledge and experience in PV technology with setting up of solar cell manufacturing untis and running them successfully. He also has in depth technical expertise in the areas of crystalline and thin film based modules. Some other important experts with NEST are Bharat Barki, director of NEST ; Jagan Mohan Rao who is a material management expert; K Vasudeva Rao who has experience in spearheaded in financing solar energy; J V Ramana who has 25 years experience in design of electronics and Manohar Reddy. NEST has generated employment for a large number of people and its employee base has increased from around 22 in 2004 -2005 to 45 in 2008 - 2009.Currently around 15 direct employees work at the head office and workshop in Hyderabad and around 7 in the factory at Bangalore. NEST also provides part time employment to many people in form of market dealers. The small businesses which manufacture charge controllers and plastic parts work exclusively for NEST employs 60 people.

NEST has developed partnerships with various governments and non government organizations such as REDCAP (Renewable energy Development Corporation of Andhra Pradesh), CREDA (Chattisgarh Renewable Energy Development Agency), JREDA (Jarkhand Renewable Energy Development Authority), MPLUN (Madhya Pradesh Laghu Udyog Nigam),Mitsubishi Corporation, Japan, Interface Europe. In addition NEST has formed partnerships with PV manufacturers such as Intelizon, Kaito, Interface FLOR and Mitsubishi.

### 10.4.5 Gaining legitimacy

NEST has gained legitimacy by developing products of the highest quality. NEST's products in the past have also received several quality certifications such as ISO 9001-2001, certifications from National laboratories such as ETDC (Electronic test development center), Fraunhofer ISE Germany, World Bank and ESMAP testing arm - PV GAP and MNRE India.

NEST also recently stood first in a survey of solar lanterns in terms of price to performance ratio conducted by German Technical Cooperation (GTZ) and Federal ministry for Economic Co operation and development, Germany. The Aishwarya solar lantern was found to give the best performance for price out of twelve solar lanterns assessed in this study. In 2005 NEST received the Ashden Award for Sustainable Energy. It was also recently shortlisted among the global top 10 social enterprises by reputed agency New Ventures India in association between CII, US Aid and British High Commission. Therefore such recognitions from renowned organizations all over the world have also helped NEST gain legitimacy.

### 10.4.6 Barriers to scaling

NEST faces barriers in terms of developing strong distribution channels with good after sales services for its products. It has also faces barriers in terms of huge subsidies on kerosene and high VAT tax on various solar energy products.

### 10.4.7 Upscaling performance in different dimensions

NEST feels that one reason why it has taken time to upscale is due to the fact that most programmes and companies in the past have focused on cheaper options instead of high quality products and maintenance services thus solar energy receiving a bad reputation. NEST however has been working extensively in this area to provide a quality service and believes they offer one of the best products and on going maintenance programmes.

**1. Quantitative**

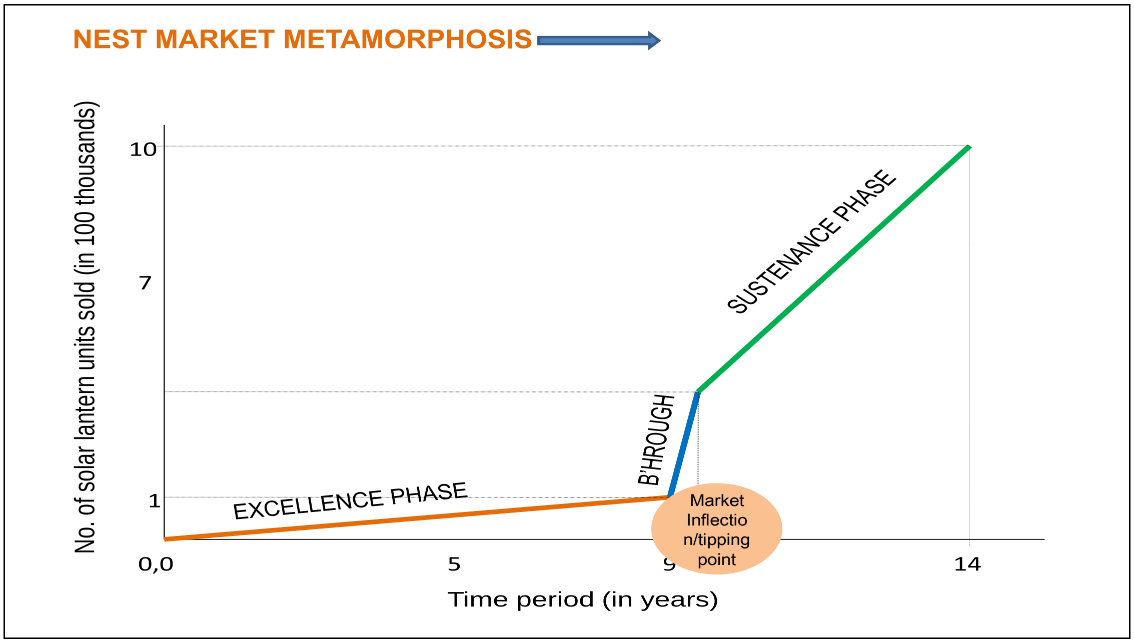


**Figure 10.4:** Number of lanterns sold by NEST over the years (Source: NEST)

NEST has sold around 78806 solar lanterns till 2008 which increased gradually from 12101 way back in 2002. NEST had only sold around 13050 lanterns in 2006 which soon increased to 6200 in 2007. The number f lanterns sold currently are around 90000 of which 80 % are sold in India and rest 20 % have been exported. NEST is also targeting 1 million solar lanterns in 5-6 years under its unique programmes such as "Solar Seeding" and "Kerosene Hot-spots" to contribute towards NEST's mission: a kerosene-free world.

**2. Net impact**

NEST has benefitted people in several ways such as avoidance of dangerous kerosene fumes; increased security in terms of having lighting around; better livelihood; helping children to study in night and also supporting people with their income generation activities.

**3.Organizational**

NEST is planning to expand its production, warehousing and marketing and sales capabilities through an investment of around INR 6 crores (1 crore = 10000000). NEST expects revenues of around INR 54.3 crores by 2014-15 and targeting an EBIDTA of around 25 % in the fifth year onwards i.e. 2015.To expand NEST, Mr. D.T. Barki is also planning of manufacturing solar panels in China due to much lower costs.

**4.Geographical**

In India NEST has a network of 70 dealers in different states in India as shown in figure 10.5. NEST has also reached 45 nations covering 5 continents. Globally NEST has reached the following major nations such as UK, Sudan, Srilanka, Japan, Australia, Malaysia, Kenya, Nigeria, Malawi, Tanzania, Fiji, Belize, Bolivia, El Salvador and Puerto Rico.

Now NEST has plans to reach other countries such as Nigeria, Somalia, Central America, Sri Lanka, Pakistan, Australia and China.

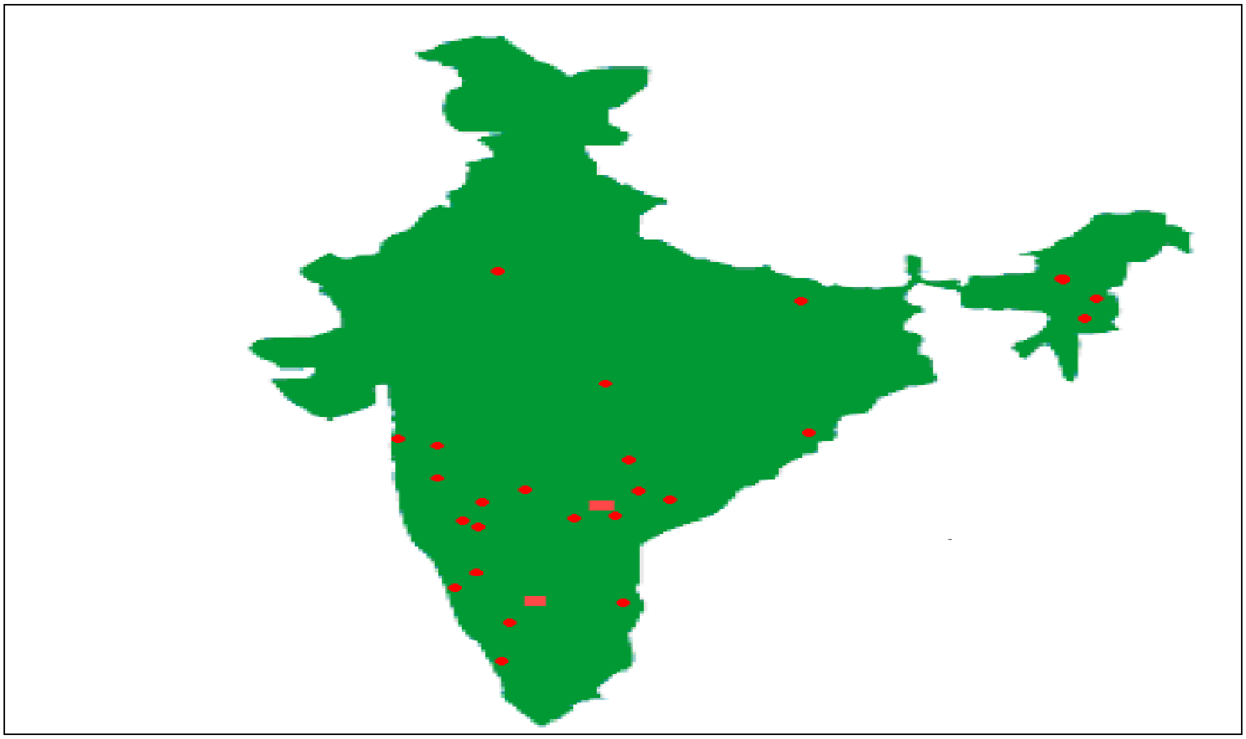

**Figure 10.5:** Geographical reach of NEST in India (Source: NEST)

**5.Depth**

In order to reach the poorest of poor NEST is trying to reduce the cost of its products by means of lease and grant schemes from World Bank/IREDA schemes. It is also planning to develop innovative financing schemes through different landlords in villages who can pay the up front cost of the solar lanterns and recover the costs from the daily, weekly earning of the poor people.

**6. Functional**

NEST is also planning to increase its product portfolio by developing new solar street lights, solar powered fans, mini solar desk lamps etc

**7.Replication**

NEST is trying to upscale by replicating by developing small businesses which manufacturer charge controllers and plastic works exclusively for NEST. It is also developing and supporting entrepreneurs in villages for distribution of its products.

**8.Innovation**

NEST is actively engaged in research and development for reducing cost of solar energy technologies. NEST has entered into a joint venture with Japanese company to use electric double layer capacitors to replace lead acid batteries in lanterns. This will reduce the cost and eliminate some of hazardous chemicals. NEST is also researching on use of LED lights in place of fluorescent tubes. In addition NEST is carrying out research on LED lights for lighting as they are better in many aspects than CFL lamps. Lately it has also collaborated with Sankeerna technologies Inc based in U.S.A. for design and development of a unique patented LED filament.

**9. Value chain**

NEST is carrying out intensive research on developing low cost grade silicon material and aims to emerge as world's manufacturing company in supply chain of solar grade starting from high purity silica/quartz. It has signed MOU with a Japanese company M Setek to work jointly on breakthrough polysilicon technology to overcome problem of silicon feedstock and has plans to become a major player in supply chain of polysilicon world over. In addition NEST is also collaborating with BHEL for production of solar cells and modules.

**10. Institutional**

Mr. D T Barki like other entrepreneurs has been advocating government to reduce the kerosene subsidies. However it has been difficult for him and other people in NEST to bring about a change in this regard.

**Conclusion**

In order to upscale further NEST should focus more on its core competencies i.e. research and development with respect to PV technology and product development capabilities. NEST should also focus on institutional scaling i.e. persuading policy makers to make regulatory changes for supporting development of solar energy.

### 9.5 D. Light Design, New Delhi

#### 9.5.1 Introduction

D.Light Design is a multinational start up initiated in 2006 by Sam Goldman and Ned Tozun while finishing their Stanford MBA as a for profit social enterprise. D. Light Design is an international consumer products company providing high quality solutions for people without access to reliable electricity. D. Light Design aims to improve the lives of millions of people and replace kerosene lanterns with clean, safe and bright lighting solutions.

#### 9.5.2 Historical Background

D. Light Design was founded in 2006 in Palo Alto, California by a socially motivated team of entrepreneurial business people and engineers namely Sam Goldman, Ned Tozun, Gabriel Risk, Xianyi Wi and Erica Estrada. D.light Design came out of Stanford Business School's Design for Extreme Affordability programme. The company was funded by prize money from business plan competitions and prestigious venture capital firms in India and the US. In 2006 Gabriel Risk joined the team to travel throughout South and South East Asia to conduct field research and test prototypes. In early 2007 D Light Design won several business plan competition including Draper Fisher Juvertson Venture challenge and the Stanford University social E challenge. Further  in June 2007 D Light got incorporated and secured funding from prestigious venture capital funds such as Draper Fisher Juvertson,Garage Technology Ventures, Mahindra group,Nexus Venture Partners and reputable social funds such as Acumen Fund and Gray Matters Capital.

In early 2008 D. Light Design relocated its operations from United Nations to New Delhi for sales and marketing and Shenzhen, China for manufacturing and production. In June 2008 D LIGHT officially released its first product line featuring Nova and Solata. In October 2008 D Light Design also secured additional funding from Nexus Venture Partners and even opened a sales office in East Africa in Dar es Salaam, Tanzania. In March 2009 D Light  Design also released Nova Mobile S200 solar powered LED light for mobile phone charging. In October 2009 D Light Design   released Kiran, one of the most affordable quality solar powered lantern in world. In January 2010 D light Design opened an international sales and product design office in Hong Kong.

#### 9.5.3 Upscaling mechanism for D. Light Design

**1. Vision, mission, ambition and expectations**

The mission of D light is to enable households without reliable electricity to attain the same quality life as those with electricity. It also wants to replace kerosene lanterns and replace them with clean, safe and bright solar light. D Light Design wants to meet the energy needs of 100 million people by 2020 and wants to prioritize customers in product design to distribution to all its operations.

**2. Learning in terms of development, financing and implementation of business model**

Here learning focuses on encouraging double loop learning in terms of developing a viable business model by challenging the conventional wisdom such as poor cannot afford sustainable energy technologies, setting up partnerships, undertaking learning and experimentation and being financially sustainable. Here we describe how D Light Design developed its learning strategies for meeting the energy needs of the poor.

**1. Products and services**

For developing its products D. light Design undertakes research spanning ethnographic and user studies, market tests, design and technology surveys for product development. This has allowed D. Light Design to develop unique products with attractive design and cutting edge technology. When designing its lanterns D.light Design has taken into account a variety of factors including the primary uses for which low income customers require lighting, the income level and demographic of the company's target customers and the environmental conditions in which potential customers live.

D. Light Design has a wide range of solar lighting products at various price points and designed and manufactured specially for the poor people. D. Light Design feels that most of development programmes in the past came up with overdesigned and extremely expensive which people could not afford. Currently the company's solar product line includes the Nova Series, the Solata (Low cost portable LED lamp), and the Kiran (one of most affordable quality solar lamp). The Nova Series is an all purpose portable LED lamp that is designed to provide brighter, safer and more affordable light for families without reliable electricity. It provides up to 12 hours of light on a day's solar charge. The Nova comes in multiple models that offer different features, including mobile phone charging. The Solata is an ultra light, highly affordable solar task lamp that is designed as a supplementary light source. It provides up to 4 hours of bright light on a full charge and is able to adequately illuminate a study area for children. Some attractive features of the products are attractive design, fast charge batteries, several hours of light with multiple brightness levels, external solar PV or AC charger, mobile charging, and battery load indicator. D. light has designed the world's most affordable solar lantern Kiran. Kiran provides up to 8 hours of bright light after a single day's charge. Kiran is durable and weather resistant and has a low price point of 10 USD making it affordable for most low income communities.

The solar lamps use a rechargeable battery which is common for sale in rural areas allowing easy replacement. The batteries are closed inside the lights and can only be recharged with the portable solar panel, which comes with safe outdoor wiring and plugs directly into the lamps. All types of lamps incorporate a circuit board and have a charging indicator LED which turns on when the product is charging. Solar panels have been designed to optimize charging efficiency under climatic conditions in North India to ensure usability of the lamps all year round.

**2. Infrastructure management**

D. Light Design sees every aspect of the manufacturing chain from product design to prototyping to production engineering to factory production to global distribution, sales and marketing as shown in the figure below.


**Figure 10.6**: Internal value chain for D. Light Design (Source: D. Light Design)

D. Light Design has built good and experienced sales and marketing teams with major distributors and local dealers to reach semi urban and rural households. It has established links with well established logistics firms which enable it to ship products to anywhere in the world. With the manufacturing and production side D Light is paying special attention to quality issues. D.light Design currently has four main offices i.e. sales and marketing and R&D division in New Delhi ; East Africa's sales office in Dar es Salaam, Tanzania; product design and international sales and marketing division in Hong Kong; manufacturing & production in Shenzhen, China.

**3. Customer interface**

For marketing and distribution and reaching the customers D. Light Design believes that engaging people and educating them about product is critical. D. Light Design has developed its own network to sell solar lanterns to sell solar lanterns and is also looking to target mass market by producing high volumes at competitive prices. D Light Design's sales and business development teams in India and East Africa use multiple channels to distribute their products within these regions such as local distributors including retailers, wholesalers, NGOs, microfinance institutions. The networks of dealers are for profit and the margin varies depending on the region and channel. The products are distributed through pre appointed preferred distributors who provide the first link in the chain to the customer and have pre existing relationships with either the customers or a network of retailers. D. Light Design offers quality products with a good after sales support mechanism provided through the distributors (warranty for products: 5 years lamp life expectancy, replacable battery after every 1-2 years) for customers and also a mechanism for regular feedback in order to improve its operations. D. Light Design also made its products more attractive if customers adapted their solar batteries to allow mobile phone charging.

To reduce the financial burden for poor consumers it has also piloted with microfinance institutions and various NGO's for appropriate consumer financing to buy its products. D. Light Design is also selling its products through corporate retail chains, which have a presence in rural areas. It has partnered with rural distribution backbone of established companies such as Godrej Industries Adhar, e choupal kiosk network ITC, DCM Hariyali and Shriram. In addition it supports rural entrepreneurs which source products from dealers and sell D. Light Design's products since people trust rural entrepreneurs more than outsiders.

**4. Financial aspects**

D. Light Design is a for profit social enterprise developed completely by the private sector with no official development aid or funds from NGOs. It has combined key components of a more traditional business model such as venture capital investment and high growth strategy with a strong focused social mission. D. light Design's main source of revenue comes from the sales of it different products. D light Design believes that a purely market and for profit based approach is one of the best for providing bright, clean and safe lighting to poor people. D light Design wants to become profitable in such a way that it does not have to sacrifice financial sustainability in the name of creating social impact. It also believes that if it has to upscale it has to be backed up by massive amounts of capital which can fund inventory, growth of new offices etc. However one of its programmes "Give Light" is subsidized but operates at a limited scale.

D. Light Design acquired USD 1.5 million as initial funding and further USD 4.5 million from 6 investors. The founders could not raise debt financing through bank loans since no financial resources or collaterals that might serve as guarantees for conventional financing institutions were not easily available. D. light Design has received funding from famous VC and private and social investors such as Nexus Venture Partners, Acumen Fund, Draper Fisher Jurvetson, Garage Technology Ventures, Gray Matters Capital, and The Mahindra Group. D light also formed partnership with Shell foundation for risk capital micro financing partnerships and market education campaigns for its products. With its continuous development D. light Design is also expecting to attract more equity funding. D. Light Design has also received approval from the UNFCCC for a carbon offset project in Uttar Pradesh and Bihar in India. The project which innovatively tracks the reduction in carbon emissions that result from D. light Design's solar lamps replacing kerosene lanterns across different geographies. The revenue from resulting carbon credits will support D. light Design's efforts to meet needs of more people. Recently D. Light Design raised USD 5.5 million from United States Securities and Exchange Commission and even secured USD 5.5. million from Omidyar network. D light is also planning to launch an IPO possibility in Hong Kong and if it is successful it can attract more investment and funding.

**5. Fit of the business model**

Although D. Light Design has developed a viable model its model faces problems due to issues such as lack of distributors who can handle inventory control and provide maintenance and working capital. Some other problems are high costs and varying nature of LED technologies and cheap substitutes in the market. Demand pressures on invoices for solar panels and high custom duties for solar energy products also create problems for D. light Design.

### 9.5.4 Human resources and partnerships

D. Light Design has rapidly grown from 5 initial employees to international team of over 70 individuals in four offices across the world in New Delhi, Tanzania, Shenzhen, and Hong Kong. At present Sam Goldman is the CEO, Ned Tozun the president and Xianyi Wu as the senior project manager. D. Light Design has a team of engineers, industrial designers and human factors specialists who specialize in developing high quality energy solutions for extreme affordability. The engineering team includes mechanical and electrical engineers as well as high volume manufacturing and quality assurance personnel. D. Light Design has around 25 people working in India, 15 in China, 11 in Tanzania,2 part time staff in US and 8 to 10 summer fellows. The employees hail from over 10 countries with expertise in product design, business development, manufacturing, sales, marketing and logistics.

D.Light Design has developed partnerships with many organizations. It has partnered with rural distribution backbone of established companies such as Godrej Industries Adhar, e choupal kiosk network of Kolkatta based ITC, DCM Hariyali and Shriram. Some prominent partnerships include Shell foundation which involves innovative and complementary financing and market awareness activities to promote solar light modules and Clinton Global Initiative for providing solar lanterns to people in Haiti.

### 9.5.5 Gaining legitimacy

D. Light Design gained legitimacy by winning awards and getting additional certifications for its products. D LIGHT Design won the 2009 Social venture network award, Global Tech 100 award, Global Clean Tech Group. It was awarded the Social Venture Network 2009 Innovation Award and named as one of the world's top 100 clean technology enterprises by the CleanTech Group.It has recently won the "Lighting Rural Tanzania 2010" competition. The Kiran solar lantern has also been honored with two top international design awards such as best consumer product design awards and Spark. The CEO of D. Light Design Sam Goldman was also selected by World Economic Forum as a 2010 young global leader. Further D Light has also been been featured in Fortune Magazine, Time Magazine, Business Week, and the New York Times. Recently D. Light Design also won the prestigious Ashden Award for Sustainable energy in 2010.

### 9.5.6 Barriers to upscaling

One of the biggest challenges for D. Light Design is to reduce prices for its products which most rural individuals find it too expensive. Insects, bugs in villages are also a problem since they crawl into the devices and make the solar lanterns stop working. With respect to administrative and operational barriers D light Design finds problems in building right sales and marketing teams to reach remote villages .It also faces problems in finding good distributors with a suitable dealer network and who are willing to take risk for distributing a new product to the low income market. Other barriers include lack of storage space for stocks in villages; lack of banking services for customers; high duties; transportation costs and increase in price of shipments. Furthermore it is difficult for D. Light Design to educate local credit officers about solar technology for financing schemes for users to buy various solar energy products as well as convincing local skilled workers to leave their stable jobs and join a new company like D light Design.

In terms of regulatory barriers D. Light Design faces barriers such as huge subsidies on kerosene, VAT and invoice tax on various solar energy products. Since D light has to import lot of components from its different offices abroad it faces custom barriers with high taxes on custom valuation, inspection and release of goods, tariff classification and submission of documents for clearance.

### 9.5.7 Upscaling performance in different dimensions

**1. Quantitative**

At the end of February 2010 D. light Design sold 1 million solar lanterns in over 30 countries. D light is is targeting 50 million people by 2015 and 100 million people by 2020.

**2. Net impact**

D. Light Design's work and product distribution has enabled thousands of households without reliable electricity to replace unsafe kerosene lamps with a safer, more affordable and more consistent supply of light and energy. By replacing kerosene lamps with solar lamps poor families can save upto 5 -30 % of their monthly income which they would spend on kerosene instead. The bright and reliable from D. Light Design's products have also supported income generating activities. Many D light Design's customers have reported an increase in monthly income by as much as 50% from the extended workday. Children are able to study more effectively often increasing their study time by 100%-200%. In one of its pilot projects in India 98% of the villagers reported high satisfaction with the lanterns while 88% reported at least one income-boosting benefit of the products. Further food preparation has become more efficient as increased light allows one to cook in the evening as well as prevent insects from getting into the food. The lanterns by D. Light Design sold to date have reduced carbon emissions by approximately 44000 tonnes each year by replacing kerosene and other fuel sources for lighting.

**3. Organizational**

D. Light Design wants to become a truly global company for distributing excellent solar energy products at affordable prices. D Light Design has also grown to over 70 employees in three years and has offices in US, India, Tanzania, China and Hong Kong. In 2010 D. Light Design centralized its product design and international sales in Hong Kong with plans to move additional corporate functions. In terms of revenue D.Light Design's total earned revenue some time ago was approximately USD 4 million.

**4. Geographical**

D. Light Design has developed a strong distribution in around 10 countries and reach with more than 500 selling points in Indian and Africa. It has also built additional distribution outlets in places such as South East Asia, Latin America, Pacific Islands and West Africa. D Light Design is planning to expand further in India, Bangladesh and East Africa with goal of selling millions of light.

**5. Depth**

In order to range poorest of the people D. Light Design has created a range of products i.e. Nova, Solata and Kiran which is among the world's most affordable solar lantern. The Kiran solar lantern has been designed and made affordable at prices as low as USD 10 to reach a large number of people. To reach poorest of customers it is focusing on earning carbon credits through the UNFCCC CDM mechanism which can provide revenues to target poorest of people for whom microfinance schemes may not even work.

**6. Functional**

D. Light Design is developing several new products such as premium solar lantern which has 4 brightness settings ; affordable solar lantern which has 360 degree lighting and is also weather resistant and quality solar task lamp which has a flexible gooseneck and can give up to 15 hours of light in a day.

**7. Replicaiton**

D. Light Design has built a base of 1500 rural entrepreneurs for distribution since the conventional supply chain route did not work for D. Light Design. Each rural entrepreneur handles around 2000 households who also source products from dealers. This rural entrepreneur network also functions as distribution network for D. Light Design.

**8. Innovation**

D. Light Design is focusing on substantial research on energy needs of low income customers, designing products that match economic capabilities of low income households, leveraging high quality and low cost manufacturing opportunities as well as developing unique distribution strategies to reach millions of people. For example D. Light Design has banned poisonous NiCd batteries from its products and is currently phasing out lead acid batteries wherever feasible. D. Light Design has also started using environmentally sound NiMH batteries which have a very limited environmental impact and last longer than lead acid batteries.

**9. Value chain**

Currently D. Light Design is more focused on creating range of low cost, high quality and reliable products such as solar lanterns and hence may not move up the PV value chain.

**10. Institutional**

D. Light Design is trying to lobby for removal of kerosene subsidies and other issues such as heavy duty structures, VAT duties etc by the Government of India. However it has not seen much success in this regard.

**Conclusion**

D. Light Design's core competency lies in high volume manufacturing, product development, research and development and global distribution. For upscaling further D Light needs to focus on its core competencies and creating strong value proposition for poor people through its products. It needs to focus more on institutional upscaling by persuading national policy makers to reduce subsidies for kerosene, reduction in high VAT taxes and new schemes for consumer financing.

## Appendix C: List of persons and organizations interviewed

**SELCO, Bangalore:** Ms. Sarah Alexander

**AURORE, Pondicherry:** Mr. Hemant Lamba and Hemant Shekhar

**THRIVE, Hyderabad E:** Dr. V V Ramani

**NEST:** Mr**.** D .T. Barki and Bharat Barki

**D LIGHT DESIGN:** Mr. Sam Goldman (Email contact only)

**In addition we also visited and interviewed**

**REDS Tumkur:** Dr. M.C. Raj

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07.07 Miguel Alvares: Design of Assessment Method for Sustainable Micro-Hydro Projects in Suriname.

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