Final Report

Understanding decentralised energy interventions and their success conditions in select countries of Asia – Pacific'

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Acronyms

ADB: Asian Development Bank
BAU: Business as Usual
BCM: Billion Cubic Meters
BGET: Border Green Energy Team
BOOT: Build-Own-Operate-Transfer
CEA: Central Electricity Authority
CNREC: China National Renewable Energy Centre
COD: Commercial Operation Date
CPSU: Central Public-Sector Utility
DDG: Decentralised Distributed generation
DEDE: Department of Alternative Energy Development and Efficiency
DESS: Distributed Energy Storage System
DG: Decentralised Generation
EEDP: Energy Efficiency Development Plan
EGAT: Electricity Generating Authority of Thailand
ENCON: Energy Conservation Promotion Fund
EPC: Engineering, Procurement and Construction
EPPO: Energy Policy and Planning office
GDP: Gross Domestic Product
GST: Goods and Services Tax
HDI: Human development Index
HPS: Husk Power System
IEA: International Energy Agency
JIBC: Japan Bank for International Co-operation
KMUTT: King Mongkut's University of Technology Thonburi
JNNSM: Jawaharlal Nehru National Solar Mission
LNG: Liquefied natural gas
MEA: Metropolitan Electricity Authority
MMT: Million Metric Tonnes
MNRE: Ministry of New and Renewable Energy
MoC: Ministry of Coal
MoF: Ministry of Finance
MoP: Ministry of Power
MOST: Ministry of Science and Technology
NABARD: National Bank for Agriculture and Rural Development
NAPCC: National Action Plan on Climate Change
NDRC: National Development and Reform Commission
NEA: National Energy Administration
NEPC: National Energy Policy Council
NPC: National People's Congress
AEDP: Alternate Energy Development Plans
PDN: Public Distribution Network

PDP: Power Development Plan
PEA: Provincial Electricity Authority
PIA: Project Implementing Agency
PMU: Project Management Unit
PPA: Power Purchase Agreement
PRC: People's Republic of China
REC: Rural Electrification Corporation
REP: Rural Electrification Policy
REST: Rural Electricity Supply Technology
RGGVY: Rajiv Gandhi Grameen Vidyutikaran Yojana
RVEP: Remote Village Electrification Programme
SHP: Small Hydro Project
SHS: Solar Home System
SIDBI: Small Industries Development Bank of India
SNAs: State Nodal Agencies
SPP: Small Power Producer
TFEC: Total final energy consumption
VEC: Village Energy Committee
VESP: Village Energy Security Project
VSPP: Very Small Power Producer
WtE: Waste to Energy

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1. Introduction and study objectives

Most of the developing countries around the world are in the trilemma of simultaneously addressing the issue of climate change, development and poverty reduction. This has made it imperative for countries in the developing world to follow the low carbon green growth trajectory. The beauty of this green growth model lies with the fact that this model has the potential to address this trilemma by decoupling the economic growth from the carbon emissions, pollution and resource use. Moreover, this decoupling is possible through an integrated low carbon growth trajectory with right technological change, market incentives and collective action.

Asia-Pacific region, one of the rapidly growing regions of the world, is at crossroads. The current development pathways of the region characterised by high carbon intensities, are unsustainable. This has been fuelled by several factors such as large-scale industrialisation, rapid urbanisation and guzzling of energy at a rate which is unsustainable. However, the rapid economic growth and consequent impact on greenhouse gas emissions are redefining the growth trajectories of the countries of the region. Renewable energy is emerging as a conduit to decouple the economic growth from its negative environmental impacts. Countries in the Asia-Pacific region continue to lay emphasis on renewable energy promotion as a prime energy agenda. Conscious and targeted policy interventions are designed and implemented to promote renewable energy. In fact, renewable energy has emerged as a promising sector that meets the avowed goals of sustainable development without compromising the environment. This has led to redefining the role of government, redirecting the trajectory of market, strategic repositioning of private players in the renewable space. Not only this, to spur and uptake the growth of renewable energy sector and to take it to a new height, a host of mechanisms are brought in place – both within domain of government as well as in the sphere of market. There has been increasing focus to introduce new policies, incentive schemes and other mechanisms to accelerate the renewable energy generation in the countries of the region.

Within the Asia-Pacific region, China, India and Thailand have emerged as remarkable economies with consciously designed focus on renewable energy promotion and growth. This gets reflected in terms of their investments in the renewable energy sector. For instance, China has increased its investment in the renewable energy sector from $ 3 biilion in 2004 to $ 102.9 billion in 2015, In similar vein, India also has expanded its investment in this sector by 22 % from 2012 reaching $10.2 billion in 2015 (McCrone et al, 2016).

A deeper reflection on the renewable energy development trajectory of the three countries of the region i.e. China, India and Thailand reveals some interesting facets of renewable energy development. China, in fact, has emerged as a global leader in renewable energy and has emerged as the largest manufacturer of solar panels and has 65 % of world's operational solar heaters. Moreover, top 10 global solar panel manufacturers are Chinese (DLA Piper, 2014). There has been specific thrust laid on export of Chinese solar products to other countries, in a situation, where China encounters some domestic hurdles. Connecting renewables with the grid has become a major complication domestically encountered in China leading to problems of domestic overcapacity and glut. This has resulted a supply push export led renewable energy sector in the country. However, the problem gets exacerbated due to specific restrictions imposed by other countries to import Chinese solar products. India, on the other hand, has emerged as a rapidly growing market economy and faces an ever increasing unprecedented energy demand. India stands as the fourth largest energy consumer globally after China, US and Russia. In addition, unlike China and Thailand, India confronts the distinctive challenge of universal provisioning of access to electrification to a large section of her population. On the other hand, despite recent episodes of political turmoil in the country, Thailand continues to lay thrust on economic development and enjoys the position of one of the fastest growing economies of the region. In terms of its emphasis on renewable energy, Thailand emerges as the first countries in the region to devise incentive structures for renewable energy as early as 1992 through a well-designed small power producers programme (SPP) programme. The prime motive behind the focus on renewable energy in Thailand is to shift from large utility scale model to decentralised forms of energy generation. Further, emphasis on renewable energy is also driven by the urge to strengthen the energy security concerns. The over reliance on Myanmar for natural gas, hydro-power import from Laos has made it imperative for Thailand to lay thrust on the promotion of domestic renewable energy sector. It has been reported that all the three countries i.e. China, India and Thailand have used the extensive trade barriers to protect their domestic energy industries. While China is deeply engaged in subsidising its domestic manufacturers resulting in global overcapacities and gluts, India's recent policy on domestic content for solar Industry is also meant to expand the domestic capacity (Bahree, 2016).

Given the prevailing commonalities and differences in the promotion of renewable energy development across the three dominant countries, an interesting facet is to compare the countries to explore and map out the existing commonalities and differences in a more detailed manner and to identify the scope to learn from each other's experiences evolved in heterogeneous settings. In addition, there also exists the possibility of replicating innovative practices, mechanisms from one country to the other. In order to make it manageable, the focus is narrowed down to the study of decentralised renewable energy systems of these countries.

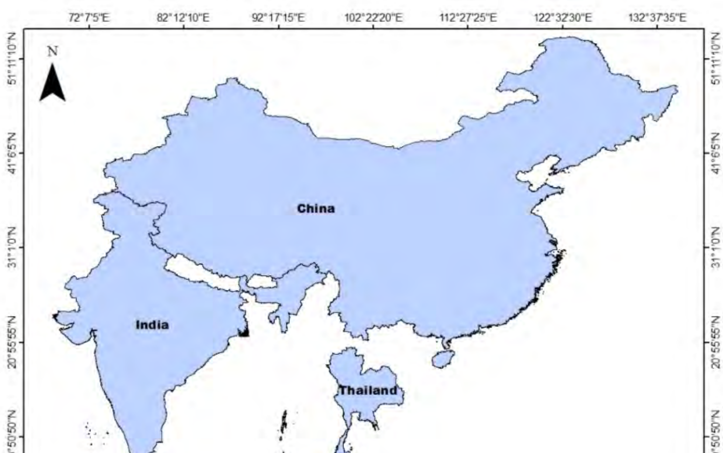

Figure 1.1: Map of the study countries

The present study in this context aims at the following set of objectives;

- To assess the policy, regulatory incentive structures supporting and promoting decentralised renewable systems in the study countries.
- To map out the variants of decentralised renewable energy interventions in terms of their business models, delivery mechanisms etc. as evolved in the study countries
- To select case studies in the domain of decentralised renewable systems which have potential to be scaled up and replicated

The study deploys a mixed method research design, built on both qualitative and quantitative research techniques. The method prioritizes collecting, analyzing, and mixing both quantitative and qualitative data at different phases in the research cycle. While the emphasis of qualitative approach is to understand the critical nuances, actors and institutions, organizations and policy instruments driving the decentralized renewable energy development in study countries, some aggregated statistical methods/techniques are used to structure the gathered information from the study countries.

The rest of the report is structured as follows. Chapter II dwells in detail about the Indian situation. Chapter III details out the country case of China. Third Chapter presents the country case of Thailand. The last Chapter offers the synthesized version of all the chapters.

2. Situation analysis of India's decentralised energy sector

2.1 Section I: Background research

2.1.1 Country profile

India, the 7th largest country with an area of 3,287,590 sq. km, occupies 2.2 % of the world's land area, and is located in the South Asia region. Geographically, India is situated to the north of the equator between 8.4 degree and 37. 6 degree of north latitude, and 68.7 degree and 97.25 degree of east longitude. The country shares land as well as maritime boundaries with eight different countries i.e. Bangladesh, Bhutan, China, the Maldives, Myanmar, Nepal, Pakistan, and Sri Lanka. The demographic attributes of India are distinctively characterized as diverse in terms of population age groups, sex ratio, and urban-rural groups. India, the 2nd most populous country in the world – with a population of about 1010.2 million, accounts 1/6th population of the world.

India has become third largest economy globally in terms of purchasing power parity. Indian economy is characterized as mix of state intervention as well as free market principles. Of late, the structural reforms introduced in the country has laid thrust on delicensing and deregulation of most of the industries including electricity sector allowing market instruments to play pivotal role in shaping the growth trajectory of the country. However, the irony is that India is home to world's largest mass of poverty ridden people with an HDI[1] ranking of 135 in 2014 amongst 187 countries. Nevertheless, there have been progresses achieved in terms of increased basic human development indicators. The literacy rate in the country has shown an improvement from 64.8 % in 2001 to 74.04 in 2011, though male-female literacy differences and urban-rural literacy do exist. India is also progressing very fast in provisioning of modern infrastructural facilities to its citizens. For example, a survey by the 'Internet in India 2014' reveals that India has crossed 300 million of internet users by December 2014.

[1] HDI i.e. Human Development Index (HDI) is a summary measure of average performance of three key attributes of human development i.e. a long and healthy life, being knowledgeable, and a decent standard of living

A federally structured political system of India while allows substantial economic and social freedom to sub-national governments, also retains crucial aspects country's development at the federal level only. The political canvass of the country has got a transformation in terms of one-party dominating politics to a multi-party dominating politics and more importantly more decentralized form of political systems and structure where sub-national governments are becoming more and more powerful. The contours of social profile of the country are manifested through multiplicity and diversity in terms of ethnicity, religious diversity and diversity in use of languages, which could be best connoted as a pluralistic form of society.

India's energy sector is expanding quickly. The past evidence suggests that while the energy use has doubled since 2000, per capita consumption is still very low with a meagre one-third of the global average. However, the key challenge lies in the current use of energy – with 3/4th of energy is sourced through fossil fuel energy sources. The projection reveals that the installed power capacity will grow from the present 300 GW to 1000 GW in 2040. This is an indication of the magnitude of change required for the sector (IEA, 2015). India is also progressing very fast in it's effort to promote renewable energy. Government of India's declaration of generating 122 GW of electricity by 2022 through renewables is an indication of the emphasis laid on renewables. Globally, wind energy development India has been one of the successful renewable energy programmes in India, which made India to stand as the 5th largest wind energy producer in the world after China, USA, Germany and Spain.

2.1.2 Energy resource and energy technologies

Energy, being the lubricator of an economy, has been put in the forefront of the country's development agenda. A fast growing and vibrant economy like India requires adequate and continuous supply of energy to keep the country moving on sustainable growth trajectory. Energy resource profile of the country while unfolds a story of vastness and the presence of diversity, at the same time also presents a scenario where a large section of population lacks basic minimum access to modern forms of energy. India is richly endowed with various commercial energy resources i.e. both exhaustible as well as renewable energy resources. In terms of specific energy resources, while coal, oil and gas constitute major exhaustible energy resources of the country, solar, wind, biomass and small hydro are the key renewable energy sources. Besides, there are also other forms of energy such as nuclear and hydrocarbon which contribute to the energy basket of the country. In the realm of renewable energy, efforts have been undertaken to produce energy from waste and bagasse co-generation sources. Globally, the country is placed as one of the leading countries with its emphasis on wind and more recently on solar energy generation. Most important and visible action in this direction is evident in the pronouncement of recent scheme of Jawaharlal Nehru National Solar Mission (JNNSM) as part of the National Action Plan on Climate Change (NAPCC).

Coal continues to dominate the energy portfolio of the country still today with the current share of about 61 % of the total installed capacity of the country. Ministry of Coal (MoC) estimates that coal reserves of the country stand at 301.56 billion tonnes as of 1st April 2014. Coal production in the country for the year 2013-14 stood at about 565.77 million tonnes. Hydro energy stands as the second major source of commercial energy in the country's energy basket. Hydro energy, at present, has a share of about 15 % of the total installed capacity of the country in 2014-15. Oil and gas contributes about 9 % of the total installed capacity of the country in the year 2014-15. Estimates of crude oil reserves of the country indicate that for the year 2012-13, the country has the reserve of about 758 million tonnes. Crude oil production statistics of the country reveal that about 37.862 million metric tonnes (MMT) of crude oils were produced in the country in the year 2012-13, whereas natural gas production of the country for the same year was about 40.679 billion cubic meters (BCM). The country imports a major chunk of its crude oil requirements from other countries. Latest import figures indicate that for the year 2013-14, about 189.238 MMT of crude oil valuing Rs 864875 crores was imported from other countries, which constitutes about 78 % of the total crude oil requirements of the country. As far as natural gas resources are concerned, 33% of the natural gas requirements were imported in the year 2012-13, to meet the growing energy demand of the country. Domestic reserves of natural gas are found to be largely concentrated in Eastern Off-shore areas (35 %) and Western Off-shore (30.68 %), barring a few other areas. Nuclear as a source of energy has been received renewed thrust very recently. At present, nuclear energy contributes a meagre of 2 % of the total energy requirements of the country in terms of installed power generation capacity. Renewable energy in altogether contributes about 13 % of the total installed capacity of the country. In absolute terms, India's renewable energy capacity has increased from a meagre 3.9 GW in 2002-03 to 33.8 GW by December 2014. However, in generation terms, renewable energy only contributes about 6 % of the total power generation of the country.

Solar as an important source of renewable energy has received renewed thrust with a new set of policies and schemes declared to accelerate the electricity generation from all forms of solar energy sources. Total installed capacity of both grid interactive and off-grid solar energy in India has crossed 3.06 GW by 2014-15. Wind energy dominates the renewable energy basket with a share of about 22.5 GW which constitutes about 67 % of the total renewable energy installed capacity.

Hydro projects up to the maximum capacity of 25 MW are considered as renewable sources of energy, as issues of rehabilitation and resettlement are not associated with such small hydro projects (SHPs). As of 31 December 2014, SHP capacity of about 187.15 MW has been installed both by the private as well as state sector. Biomass energy sources, both biomass and co-generation sources of energy also constitute an important source of energy for the country. The total estimated energy generation potential from the biomass power is about 25,000 MW. More than 300 projects constituting in total about 4000 MW capacity has been installed by December 2014, which constitutes about 12.6 % of the total renewable energy installed capacity of the country. In addition, there are around 30 biomass projects under construction constituting about 350 MW capacities.

2.1.3 Energy services and energy requirements

Energy demand in the country has registered a heavy growth in tune with the economic development of the country. The demand for energy has outpaced the supply of energy resulting energy deficits in the country. Deficits are presented in terms of energy deficits and peak deficits. In terms of electricity deficit, Central Electricity Authority (CEA) reports that for the year 2014-15, energy deficit was in the tune of 3.6 % of the availability and peak deficit was around 4.7 % of the availability. Energy deficits, particularly power deficits in the country, are primarily due to scarcity of coal - resulting from problems associated with political economy of allocating coal mines to the power generating companies, environmental constraints in the form of no-go areas and of course due to financial issues with the discoms.

Projections reveal that energy demands for the country will be highest globally surpassing the energy demand of China in 2030. It is also projected that by 2030, in order to meet the growing energy demand, India will import a substantial part of her energy, despite growing energy production from non-conventional sources. It is posited that while India's production will rise 112 %, consumption will increase by 132 %.

The electricity requirement projections indicate that the country requires 800000 MW of electricity by 2031-32 from the current level (GoI, 2006) to sustain the current growth momentum of the country. Further projections caution that the peak power deficit could rise to 70,000 MW by 2017. Moreover, the challenges are more pronounced when it comes to providing energy access to the millions of people lying in the bottom of the pyramid.

Energy services in terms of provisioning of energy for the deprived people in India do not reveal an encouraging pattern . CEA studies indicate that though grid has reached to 97 % of the villages, however, 250 million people do not have access to reliable electricity supply. There exist large inter-state variations in terms of electrification achievements. While all households in Andhra Pradesh, Punjab, and Kerala have electricity, electrification of households is limited to 73.5 % in Bihar, 58.5 % in Uttar Pradesh and 36.8 % in Assam. Both grid and off-grid modes of energy delivery systems have been utilized to enhance the access. While grid has been the dominant mode of electrification in the country, off-grid systems have recently been prioritised.

2.1.4 State of decentralised energy systems

Decentralized energy is the generation of power closer to the demand centre, primarily designed to fulfil the local energy needs (Kaundinya et al. 2009). Often both power and heat are produced close to the demand centres. Research studies indicate that (Mishra et al, 2016) even there do not exist consistent definitions and several terms e.g.

decentralised energy, distributed energy, off-grid systems and standalone systems are used interchangeably to suggest the on-site production and consumption of electricity. A widely used definition is by the IEA, suggests that decentralised energy system as 'a generating plant serving a customer on-site or providing support to a distribution network and connected to the grid at distribution level voltages'. Broadly, there are two major types of decentralised energy systems i.e. grid connected and off-grid . In case of grid connected systems, the plants are often connected to the centralized grid based systems and feed the extra power to the centralized grid. However, in case of off-grid projects, electricity generated locally are used to meet the local demand. Within the off-grid space, there are largely three different categories of products considered i.e. small lighting devices such as solar lanterns, home lighting systems and mini-grids.

In the present context, the focus is more on off-grid energy systems or decentralised energy systems, as grid integrated distributed systems are on a very nascent stage. Various off-grid technological options have been developed, inducted, tested on the ground. A number of technologies such as combustion and gasification of biomass, micro-hydro, solar photovoltaic, aero generators, waste to energy bio-fuel gasification plants are used at different scales and sizes. In practice, however, only a few technologies such as biomass gasification, micro-hydro are extensively used as predominant technologies in the country (Hiremath et al, 2009). These technologies have been used in various sectors such as agricultural, industrial, domestic and commercial. In terms of size of these small scale off-grid decentralised systems, they range from a small size of 2 kw often called pico- power to a relatively larger size of about more than 100 KW.

The history of decentralised energy technologies in India goes back to as early as 1940s with focus on biogas and improved cook stoves, while other technologies followed suit over time. The National Biomass Policy originated in 1970s for the first time emphasized on promotion of biomass technologies. Oil shocks of 1970s also acted as a dominant trigger to look for alternative sources of energy. Micro-hydro systems as an alternative option were explored during the oil shocks of 1970s. However, more systematic emphasis was laid around late 80s and early nineties. Various R & D and pilot project based decentralised experiments were made around early 1990s However, reform act

2003 further opened up the market for private sector led decentralised energy development in the country. Similarly, in the field of solar energy, India has more than two decade of experience. The ministry at the central level i.e. Ministry of New and Renewable Energy (MNRE) has been putting sustained efforts to promote various forms of decentralised energy systems including solar. The reform carried out in the power sector with the enactment of the Electricity Act 2003 further added impetus to the promotion of decentralised energy systems by ushering an era of de-licensing and encouraging private participation in the field of decentralised energy systems. Further withdrawal of legal and regulatory hindrances has augmented the promotion of decentralised energy systems in the country. Several policies and programmes have been announced from time to time to promote decentralised energy systems. The most recent one is the Mini-grid Policy of 2016, allowing a proper framework for the private sector investors and offering scope to address certain complex regulatory issues.

The solar programme of the country is two decades old. MNRE has put in place a sustained effort to promote various forms of rural electrification. Most recent programme is the Jawaharlal Nehru National Solar Mission (JNNSM), where 2000 MW of off-grid component is demarcated. Largely solar PV based technologies have been used as an off-grid technology in India. Various technological options such as solar lanterns, solar home lighting systems and solar energy based mini-grids are promoted. Along with this, roof-top solar systems are also promoted in the process, MNRE has gathered large amount of experience in technical, socio-political, management and governance dimensions of decentralised energy management.

Biomass as an off-grid option has been used for producing electricity by using locally available biomass resources such as wood chips, rice husks, *arhar* stalks, cotton stalks and other agro base residues. Biomass based off-grid systems are energised largely through the Government of India's programme 'Remote Village Electrification Programme (RVEP) and Village Energy Security Programme (VESP). However, the VESP programme was discontinued due to its poor success. Latest statistic shows that about 150 MW equivalent biomass gasifier systems – both grid and off-grid, have been installed.

Mini and micro hydro systems have also been set up in remote and isolated areas – mainly in Himalayan and Western Ghat regions. The total installed capacity of small hydro projects (capacity up to 100 kW) by 2015 was about 4162 MW consisting of 1048 small hydro power projects.

2.1.5 Variants of decentralised energy systems

Decentralised energy systems exist at different levels and scales in the country and can be characterised as heterogeneous in many ways. At the village level, the primary motive is to provide electricity to fulfil the rural energy needs. At the industry level, the primary emphasis is to energise the industry and feed the excess power to the grid.

In the off-grid space two different technological options are largely employed i.e. individual solutions (stand-alone systems) and collective solutions. The individual solutions which normally consist of small ready to use kit based systems are systems such as solar lanterns, solar lamps, solar home lighting systems (SHSs) and often some battery operated small systems. On the other hand, collective solutions provide electricity to the entire village or a cluster of households and use technologies such as solar PV, micro/mini hydropower, biomass based technologies – with or without storage. However, the most common technology used for off-grid systems is the solar PV technology and mini/micro hydro systems.

Various delivery options have evolved over years to provide off-grid energy systems in the country. These options depend on the mode of delivery (product sale or local grid based supply), financing mechanism. For stand-alone systems, broadly four delivery options are found in the country such as cash sales by the retailer, rental fee based service based delivery model, leasing arrangement and micro-finance based scheme. In the field of solar home lighting systems, SELCO, a private enterprise based model has promoted the lease- to-own based model, while TERI's lighting a billion lives campaign employs fee based rental model for disseminating solar lighting based solutions in India.

In the field of collective solution, a number of alternative options were evolved over years. These options can be grouped under primarily under two dominant categories. One of the major options was publicly supported and NGO/Community managed models. Most of government supported programmes such as Village Energy Security Programme (VESP) and Remote Village Electrification Programme (RVEP) follow this model of creating Village Energy Committees (VEC) or Rural Energy Cooperatives to manage such projects. In such projects, VEC plays an important role of a power producer, distributer and supplier of electricity. The Figure below presents a typical model funded by publicly supported schemes (Figure 2.1).

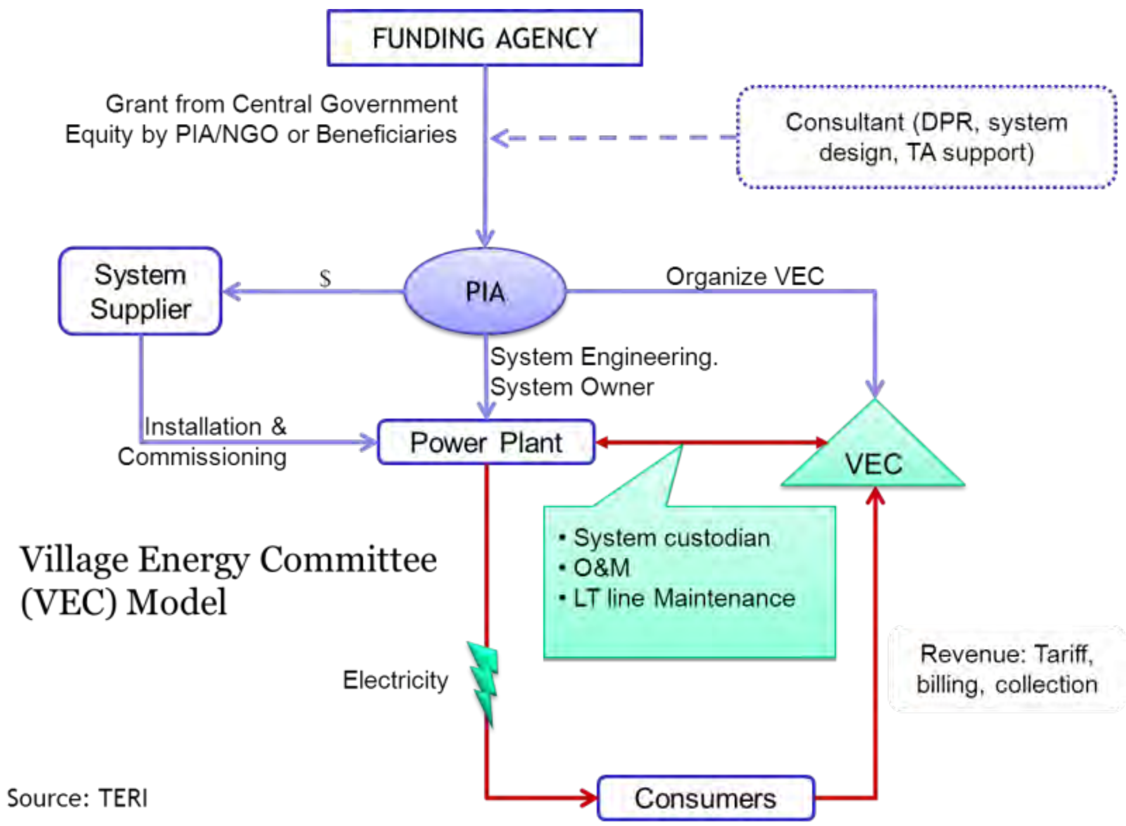

Figure 2.1: Publicly supported VEC model

The second important option is private sector led model (Figure 2.2). The enactment of the Electricity Act 2003 opened up the off-grid or decentralised energy sector to the private investors. As a result of which, private investors have increasingly shown interest in the off-grid or decentralised energy business. The models promoted by private investors are purely service and demand driven. While major management issues are with the private developers. Tariffs are decided on negotiation basis keeping financial viability of the project in mind as well as affordability of the consumers. A typical private sector led model is the Husk Power System (HPS) in India, which has deployed more than 300 rice husk based mini-grid decentralised plants in the state of Bihar – one of the least electrified states in India.

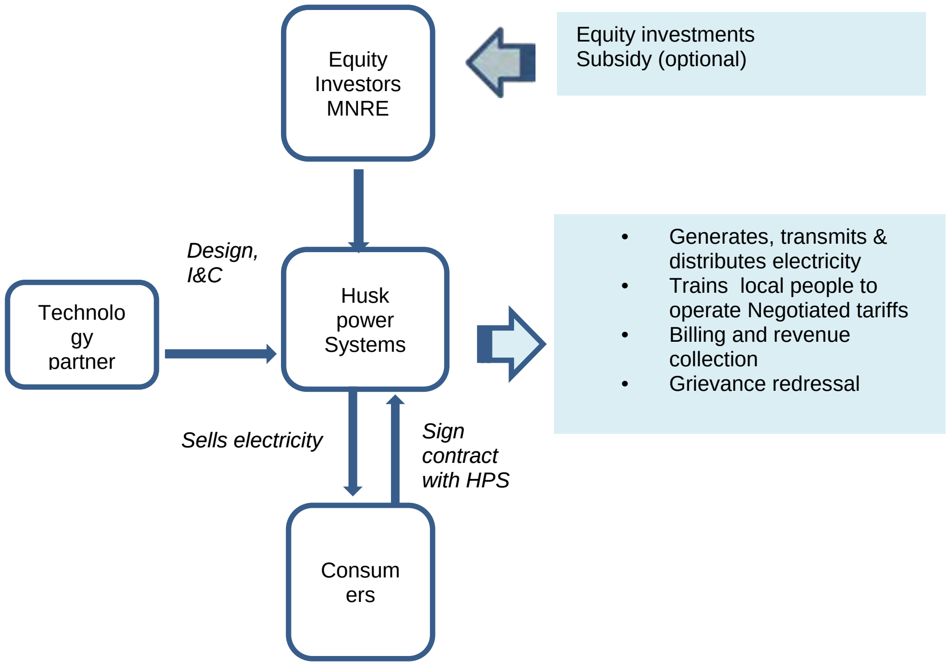

Figure 2.2: An example of typical private sector model

Having discussed the variants of decentralised energy systems in India, it is interesting to assess the policy and regulatory system governing the decentralised energy development in the country.

2.2 Section II: Assessment of country specific policy, regulatory and other incentives

India, with its quasi-federal constitutional structure, has clear demarcations of legislative and executive powers between the Central Government (Federal Government) and State Governments (Provincial Governments) Legislative powers over the subjects are specified in the Seventh Schedule of the Indian Constitution under three different lists: Central list (List I), State list (List II) and Concurrent list (List III). Electricity, being an item in the concurrent list, is the responsibility on both the federal as well as the provincial governments to legislate on matter.

Over years, a set of actors and entities have evolved both at the federal level as well as at the provincial level to manage, operate and execute the electricity sector in the country. At the federal scale, a whole bunch of ministries are engaged in different capacities to drive the country's electricity sector in general. For instance, Ministry of Power (MoP) is engaged in the promotion of power sector by evolving policies for the sector in general. One of the key responsibilities of the Ministry, *inter-alia,* is to promote and enhance the rural electrification in the country by designing the electrification schemes and dealing with the issues relating to power supply/development. It aims at promoting decentralised and distributed generation in the states/provinces and Union Territories. Another important Ministry at the Federal level is the Ministry of New and Renewable Energy (MNRE), which is serving as the nodal Ministry at the Centre in the promotion of renewable energy – both for grid based as well as off-grid interventions. Key goal of the Ministry is to 'develop and deploy new and renewable energy for supplementing the energy requirement of the country'. The Ministry has been assuming increasing significance on the face of growing need to ensure the energy security and emerging concerns related to climate change. Two of the five missions of the Ministry are relevant in the present report purpose; 'Energy Availability and Access', and 'Energy Equity' with the goal to achieve the energy per capita consumption at par with the global average by 2050. MNRE is the prime Ministry for the promotion of off-grid/decentralised energy sector in the country. Various promotional measures have been undertaken from time to time by MNRE as well as various state governments to mainstream renewable energy based including decentralised renewable energy options. Along with these two ministries, there exist a whole lot of entities and actors, forums, associations, non-state actors with different roles and responsibilities engaged in driving the electricity sector in the country. We will discuss about these schemes and programmes in detail in this section.

At the state level, efforts have also been taken to enhance the rural electrification in their respective states. One of the initial efforts in this direction was the creation of state nodal agencies (SNAs) for promotion of renewable energy. These agencies were created around 1980s in most of the states, to demonstrate renewable energy technologies, giving training to local people, generating awareness amongst people about the use and importance of renewable energy technologies. State level electrification schemes have also been declared in several states to promote rural electrification in the respective states. For instance, Gujarat has evolved a scheme called '***Jyotigram Yojana***' in 2003 under the leadership of Mr Narendra Modi, then the Chief Minister of Gujarat. The scheme was envisaged as participatory scheme between the government and local communities. The scheme was largely funded by government grants. The scheme aimed at providing 24 hours three phase quality electricity to the rural areas of the state . The designing of the scheme led to segregation of agricultural load from other uses such as residential, industrial and commercial. By 2006, the scheme was implemented throughout the state covering about 18,000 villages and 9700 hamlets. Similar schemes were also introduced in other states such as ***Biju Gram Jyoti Yojana*** of Odisha introduced in 2007-08. The scheme aimed at electrifying villages having population less than 100. State Government supports 100 % budgetary support for the scheme.

Apart from above, state specific policies also have evolved in many states to support rural electrification schemes largely through decentralised renewable energy modes. Latest statistics of MNRE Suggests that about 15 states have drafted state specific solar policies. Interestingly, most of these policy pronouncements do cover renewable energy based decentralised energy as an option of power generation and rural electrification. Some states also have evolved state specific mini-grid policies. For instance, state of Uttarpradesh has come up with 'UP Mini-grid Policy'to promote decentralised generation of clean and green power. There are also states like Maharashtra which are in the process of finalising state specific mini-grid policies. The proposed Maharashtra Mini-grid Policy aims at promoting roof-top solar power generation and other forms of decentralised energy generation.

Tracing the history of rural electrification in India reveals that the initial attempts were limited in scope and ambit, largely sporadic and characterised by no specific policy thrust for rural electrification. At best, most of the rural electrification policies were considered as strings of larger rural development programmes/policies/schemes (Siddiqui and Upadhyay, 2011). The early attempts to renewable energy based decentralised energy projects were developed as demonstration projects by state nodal agencies. The Rural Electricity Supply Technology (REST) Mission declared in 2002, for the first time laid emphasis on renewable energy based decentralised energy generation technologies including mini-grids. The Mission, for the first time, proposed an integrated approach for rural electrification, with the objectives 1) to identify and adopt technological solutions, 2) to review the current legal and institutional framework and make changes whenever necessary, 3) to promote, fund, finance and facilitate alternative approaches in rural electrification, and 4) to coordinate with various ministries, apex institutions and research organisations to facilitate meeting national objectives. Around this time also, a committee named as Gokak Committee was formed to look into the issues related to decentralised energy generation – in particular with specific thrust on off-grid modes of electrification. The Committee recommended that a decision between grid based and off-grid electrification would be based on 1) the distance from the existing grid; 2) load density; 3) system losses; and 4) load management. Recognising the cost differentials in setting up renewable energy – based mini-grids and other decentralised options, the Committee observes that

"It is necessary that the socio-economic benefits that accrue to a local community on account of such scheme are evaluated; while appraising it on the benefits accruing to a single stakeholder may

not justify the project cost, the totality of the benefits accruing to the various stakeholders may more than justify the same".

This was followed by the Electricity Act of 2003 with the overall objective of developing the electricity industry in all respects and providing electricity access to all areas. Two specific policies, which evolved as offshoots of the Act i.e. Rural Electrification Policy (REP) and National Electricity Policy (NEP) aimed at accelerating the process of rural electrification in the country through renewable energy based decentralised energy systems, *inter alia*, other measures. The Act itself laid emphasis on the promotion of renewable energy based decentralised/off-grid solutions. For example, Section 2(63) of the Act talks about promotion of distributed generation through stand-alone energy systems as a model for rural electrification in addition to grid based rural electrification. The Act through its de-licensing provisions opened the door for the private sector to venture into domain of rural electrification through decentralised modes. Most recent efforts undertaken in the direction of renewable energy based decentralised system promotion are through the declaration of amendment of Tariff Policy 2006, done in 2016 and National Policy for Renewable Energy based Micro and Mini Grids 2016. Amendment of Tariff Policy 2006 puts emphasis on supply of power to remote unconnected villages through mini/micro grids. The amendment to Section 8 of the Tariff Policy states specifically about promotion of renewable energy based decentralised energy systems. To quote the amendment ;

"…Micro-grids supplying renewable energy are being set up in such areas where the grid has not reached or where adequate power is not available in the grid. Investment involved in setting up of such micro grids is substantial. One of the risks of investment is grid reaching the area before the completion of the project life and thereby making power from micro grids costly and unviable. In order to mitigate such risk and incentivize investment in micro grids, there is a need to put in place an appropriate regulatory framework to mandate compulsory purchase of power into the grid from such micro grids at a tariff to be determined under section 62 of the Act considering depreciated cost of investments and keeping in view industry benchmark and with a cap if necessary, as approved by the Appropriate Commission. The Appropriate Commission shall notify necessary regulations in this regard within six months."

Promulgation of National Policy for Renewable Energy based Micro and Mini Grids 2016 also highlighted the importance of promoting renewable energy based mini-grids for enhancing access to electricity in both un-served as well as under-served regions of the country. It was also envisaged in the Policy that mini-grids also provide livelihood creation in the local regions by energising the productivity based enterprises.

Apart from policy support provided from time to promote and accelerate the decentralised energy systems in the country, specific programmes were designed and implemented from time to time to promote off-grid or decentralised energy systems in the country. Programmes such as Remote Village Electrification Programme (RVEP) and Village Energy Security Programme (VESP), Decentralised Distributed Generation (DDG) scheme of *Rajiv Gandhi Grameen Vidyutikaran Yojana* (RGGVY), off-grid component of RGGVY are the major programmes initiated by the Central Government to drive the decentralised renewable energy systems in the country. The evolution of such programmes is mapped in the Figure below (Figure 2.3).

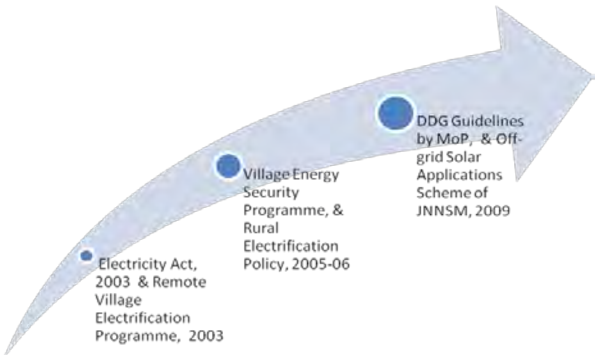

Figure 2.3: Evolution of renewable energy based decentralised energy programmes in India

While RVEP, VESP and JNNSM programmes are undertaken by MNRE, DDG was part of the RGGVY scheme by the Ministry of Power (MoP). RVEP programme was designed to provide the lighting requirements through decentralised routes, on the other hand VESP programme was structured in such a way to offer total energy needs with specific emphasis on the use of locally available biomass resources. The implementation strategy of the RVEP follows the following steps such as identifying the remote village by Rural Electrification Corporation (REC), setting up of coordination panel for the programme at the central ministerial level as to avoid the duplication of efforts, awareness creation through training and orientation programme for the government, conducting surveys to assess the available local resources and energy requirements etc. Under RPEP programme, technologies such as solar home lighting systems (SHS) and solar PV power plants, small hydro-power plants (SHP) plants, biomass gasification systems with 100 % producer gas engines are included. It has been reported that SHS and solar power plants have been implemented in major habitations through RVEP programme. These projects are largely implemented and owned by the state nodal agencies (SNAs). One of the programme requirements was to form energy committees to manage and operate the projects at the plant level. On the other hand, the VESP programme which was envisaged by MNRE and launched in 2009 focussed on providing total energy solutions such as household cooking and lighting requirements, street lighting, and commercial energy demands such as shops and flour mills to the remote areas of the country. The programme was structured as a community led initiative. The objective of the programme was to meet the energy requirements through biomass based conversion. The project implementation strategy involves using participatory tools to identify the needs of the villagers, formation of village energy committee (VEC) as a custodian of the project. The DDG scheme of RGGVY is also provided the necessary impetus for the promotion of decentralised energy systems in the country. The scheme was designed to electrify villages with a population over one hundred, where grid extension is not foreseen in the next five to seven years. These projects are implemented by State Nodal Agencies (SNAs), state utilities and/or the identified Central Public Sector Utilities (CPSUs) through project developers, with ownership vested in the state governments. DDG scheme also lays emphasis on reaping the benefits of cluster based approaches. One of the eight missions of the National Action Plan on Climate Change (NAPCC) i.e. Jawaharlal Nehru National solar Mission (JNNSM) also has a component related to off-grid solar energy development. The Mission aims at promoting 2000 MW of off-grid solar energy in the country by 2022. The Mission recognises that off-grid solar energy applications have huge potential to energise rural and remote areas of the country.

Through these programmes and policies various incentive schemes were also designed to propel the off-grid or decentralised energy generation in the country. The incentive schemes can be grouped as financial incentives, fiscal incentives and other forms of incentives. Under the fiscal incentive scheme, various subsidies such as capital subsidies, operational subsidies, and interest subsidies are provided. In most of the cases, 90 % of the benchmark capital cost is subsidised. The interest subsidies are channelled through non-banking financial institutions and scheduled commercial banks like National Bank for Agriculture and Rural Development (NABARD), Small Industries Development Bank of India (SIDBI) etc. Apart from this, some other fiscal incentives are also provided in the form of tax holidays, exemption of goods and services taxes (GSTs) in some states, relaxation of import duties to the promoters of decentralised energy systems in the country. A broader view on various subsidy schemes is provided in the Table below **(Table 2.1).**

Scheme	Subsidy vehicle	Structure of the Central Financial Assistance (CFA)
RVE	Capital Subsidy subject to upper limits	90% of the costs of various renewable energy devices/systems subject to pre-specified maximum subsidy *Maximum CFA per household is US$ 360* 1US $ - INR 50
VESP	Capital subsidy Operational subsidy for first 2 years	90% of the total project cost *Maximum CFA per household is US$ 400* 10% of the total project cost
DDG under RGGVY (now Deen Dayal Upadhyaya Gram Jyoti Yojana)	Capital subsidy Operational subsidy for 5 years	990% of the total project cost 10% of the total project cost
Off-grid component of JNNSM	Capital and Interest subsidy	US$ 1.8/W_p(With battery storage) US$ 1.4/W_p(Without battery storage) Soft loan @5% p.a.

Table 2.1: Incentive schemes under various decentralised schemes in India

A critical assessment of the policies, regulations and incentive scheme suggests that the policy environment governing the decentralised energy systems in the country is characterised by its dynamic nature of evolution. One of the basic aspects related to the policy dynamics is closely linked to the 'definition of rural electrification', which has got transformed multiple times depending on the political economy exigencies and requirements. The emphasis in recent years is laid more on the electricity delivery aspects rather than nominal recognition of 'a village getting electrified'. Another aspect of dynamic policy and programme process is related to the recognition of climate related concerns in the recent policies and programmes. For instance, DDG programme explicitly mentions about the role of carbon financing, which is not mentioned in any of the programmes. However, there also exist several concerns in the existing polices, incentive schemes. For instance, it is reported that there exist lack of coordination between different ministries in dealing with decentralised/off-grid electrification. Contentions run that the existing approaches to disburse subsidies are skewed in nature – only promotes publicly supported programmes (Mishra et al., 2016).

2.3 Section III: Case study modules

2.3.1 Programme specific case study: Village Energy Security Programme (VESP) of Government of India

1. Background information

The VESP programme envisaged on the backdrop that energy is critical for the economic development of an economy. More importantly, the provision of basic minimum access to modern energy can transform the life of the people by providing them range of benefits such as health facilities, education facilities, empowering women, mechanisation of agricultural systems etc. who are deprived of it. The idea to provide total energy solution through this programme was conceptualised in tune with the India's Eleventh Five Year Plan (2007 – 2012) where emphasis was laid on using the available rural biomass to generate energy and consequent provision of socio-economic opportunities at the village scale. It was also contemplated in tune with the goals set during that time to achieve universal electrification by 2012. It was structured as a community driven biomass programme and also expected to contribute to the climate goals of the country by capitalising the available renewable energy resources of the country. The emphasis was laid on achieving energy security at village level. The conceptualisation of this programme was envisaged building on the report of the Integrated Energy policy (IEP) which projected that traditional biomass will be mainstay as a primary source of fuel for rural India in long time to come. Given the understanding that woody biomasses are locally available and at present used inefficiently by the rural communities, it was premised that if this available local resources can be tapped in an efficient manner, it can meet the unmet rural energy requirements.

Considering all this, VESP was launched in 2005 by MNRE as an integrated project by consolidating several isolated electrification programmes and a number of vertically run cooking energy programmes. As mentioned above, the focus of the programme was on 'meeting the total energy requirements of cooking, lighting and productive use by using locally available biomass resources. The programme was conceived by MNRE as one of the innovative and unique programmes designed in India. The programme was rolled out initially as a pilot programme primarily intended to test the workability of the concept and readiness of the institutional arrangements to manage the project. Technical support for the programme was provided by the World Bank. The technical assistance provided by the World Bank was aimed at evaluating the sustainability of institutional arrangements and business models of pilot projects implemented in eight states. Total numbers of projects sanctioned by MNRE were about 67. However, only 45 projects were commissioned under this programme.

2. Rationale

The rationale for choosing this programme was based on the fact that this programme was one of the unique decentralised programmes ever conceptualised and tried out in India. The uniqueness is echoed in its emphasis on 'total energy solutions' to address the rural energy challenges and constraints. The programme was premised with the assumption that availability of rural biomass could act a panacea to address all the energy related concerns in the rural areas.

However, it is also interesting to explore that despite the uniqueness of the programme; the programme could not succeed and was discontinued in the middle. From the research perspective, it is fascinating to explore the factors that led to the discontinuance of the programme. Also, it is interesting to identify the set of challenges that was encountered in the operation and management of the projects under this programme and possible solution that would have minimised the risks encountered.

3. Methodology

The programme was analysed by reviewing several secondary sources materials, literature on the programme, study reports, project specific reports on the programme. This was supplemented by conducting regular stakeholder interviews with government officials who were entrusted to look after this programme both at the federal level as well as the provincial level. Interviews were also conducted with experts in the field of decentralised energy who were directly or indirectly engaged in the project formulation, management, and operation of the project. Some telephonic interviews were also conducted with state nodal agency officials and other stakeholders to elicit information related to the operation, management of the programme or projects under this programme.

The collected information are analysed to assess the key aspects of the programme in a systematic way. The analysis is done to structure the available information in certain way to draw some meaningful conclusion.

4. Key characteristics

One of the major characteristics of the programme was based on its systematic approach to energy security at the rural village level.

As mentioned above, one of key features of this programme was that it aimed at providing total energy solutions to the rural community in the country. The focus was also laid on use of energy for domestic use as well productive use. One important dimension of use of energy through these projects was meeting the cooking energy requirements through community and/or domestic biogas plants and provision of efficient cook stoves (such as gasifiers, turbo or fixed cement concrete stoves).

Another key aspect of the programme was its focus on creating a complete supply chain at the village scale, the forward link was created by generating productive enterprises and the backward link was created by linking the project to energy plantation at the local scale.

An important aspect of this programme was the project management by the village committee called village energy committee (VEC) to operate, own and manage the project. While this was aimed at generating a sense of ownership amongst the villagers, it also had several flaws in it.

The programme was also designed to create a pool of technical people at the local level by giving them training and skill sets to manage the projects.

Yet, another main feature of the project was related to the provision of grants for the projects. Substantial amount of capital costs of the project were provided by the central government as grants. Along with the capital subsidies, some amount of subsidies was also provided to take care of the O & M costs of the projects for a few initial years.

5. Technology

The programme was envisaged to use biomass gasifiers, biofuel, biogas and/or hybrid systems. The programme was designed to capitalise the three biomass based technologies i.e. electrification either by a diesel generating set run on straight vegetable oils (such as by using non-edible oils such as Pongamia and Jatropha) or a biomass gasifier of size of about 10 – 20 kW range, energising a 100 % producer gas engine. Along with this, improved cook stoves or biogas based cooking energy provisions were also made as part of the project. In total, about 700 kW of electricity generation equipment was installed through these project interventions. The projects were so designed that it could generate local livelihood by creating productive enterprises at the local level.

6. Energy service

The projects deployed through this programme were designed to provide complete energy solutions. Complete energy solution in the form of meeting the domestic requirement, as well as requirement of agricultural energy and creating productive enterprises at the local level. In addition, it was also intended to energise the local enterprises.

Energy services to the local people, in most of the cases, were contingent upon the fact that every household will provide the fuel wood on a rotational basis. It was found that this did not work in most of the cases.

7. Delivery mechanism

The design of a project under this programme is based on the village energy plan, which is prepared as part of the initial survey of the village. The initial surveys conducted as part of the programme are participatory in nature involving the communities. Community mobilisation and formation of new institutions such as VEC are the key activities during the initial phase of project conceptualisation. A village energy committee (VEC) is formed as sub-committee of Gram Panchayat to take care of the project operation and management at the village level. VEC is asked to procure the power generating equipment through a process of competitive bidding. VEC is responsible to arrange the biomass fuel either as part of the contributions from each beneficiary on a rotational basis or can devise a system of procuring the same by paying for the fuel. VEC is encouraged to engage themselves in energy plantation for sustainable supply of fuel wood.

VEC is formed by the project implementing agency with representation from the village and local governing entity such as Village Panchyat. Gram Sabha is called to form the committee and the committee is formed as a 'sub-committee' or 'standing committee' of the Gram Panchayat based on the State Panchayat Raj Act and rules. VEC consists of 9 – 13 members – of which 50 % of them should constitute women member. Usually, the elected panchayat member of the village should be the ex-offico members of the committee.

While the implementing agency set up the plant and hands over the plant to the VEC for day to day operation and management of the plant. The Committee becomes the care taker of the plant and deals with the day-to-day management of the plant. A distribution line in the form of mini-grid is laid down to supply electricity to the households. Electricity is provided at a tariff mutually agreed by the VEC in consultation of Project Implementing Agency (PIA). The designed capacity of the project is decided based on the energy demand survey and keeping in consideration of the future demand for energy.

8. Financial structure

The programme is heavily subsidised by the government. Central government funding is channelized through state nodal agencies (SNAs). A onetime grant of about up to 90 % of the investment cost is provided by the central government. Along with this, to bring in a sense of ownership, an equity contribution was also expected from the beneficiaries either in kind or in cash. In addition, an operation and maintenance support fund is also provided to meet the O & M expenses for two years. The VEC is accordingly asked to create two bank accounts – one for capital subsidy and the other for O & M subsidy. VEC, being a sub-committee of the Gram Panchayat is subject to audit of account and have to report regularly all the financial transactions related to the project.

Tariff setting is done by the VEC in consultation with the Project Implementing Agency (PIA). Tariff is set at the level to meet the fuel costs and costs of O & M.VEC is also entrusted to create a village energy fund under the provisions of State Panchyat Raj Act from the contributions of beneficiaries. The monthly user charges collected are deposited in this fund. The management of the fund rests with the committee with two signatories – the Gram Panchayat Member and President/Secretary of the Committee. The overall management and operation of a typical project implemented under VESP programme is presented graphically below (Figure 2.4).

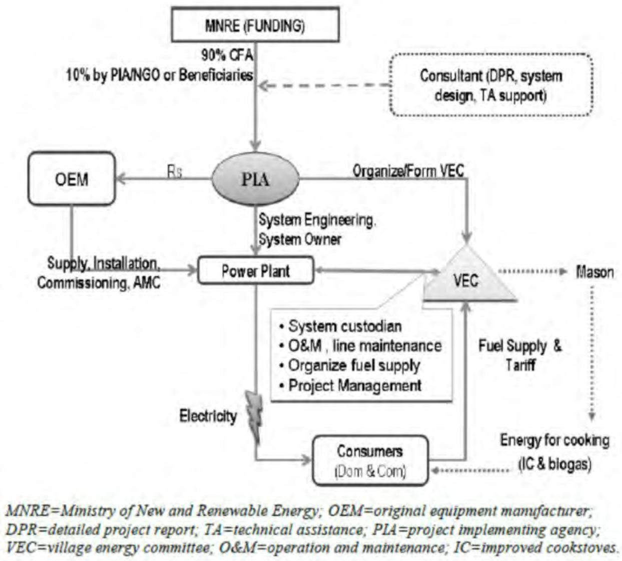

Figure 2.4: Village Energy Committee Model (Source: TERI, 2009)

9. Driving factors

As pointed out above, though this programme was considered as a uniquely conceptualised programme by the Government of India, it was discontinued after a few years of trials. It is worth exploring to identify the key factors which led to its discontinuance.

One of the major reasons for the failure was the poor institutional arrangement to manage the projects. A survey done by the World Bank revealed that this lack of institutional coordination was evident at different layers of governance. One layer of such poor coordination occurred between MNRE at the centre and State level stakeholders at the provincial level – in particular the coordination between the MNRE and State Nodal Agencies (SNAs). The second layer of this poor coordination is reflected between the SNAs and implementation of the project. It is reported that SNAs do not find it interesting to engage themselves with the implementation as these projects are characterised by small scale and community driven projects (World Bank, 2011).

Technological factors which acted as a constraint for the success of the project include lack of adequate training and creating the local level technical skill sets to manage the projects. Fuel availability was also a challenge for the project. It was reported that fuel supply was not organised properly. This adversely affected the uptime of many VESP projects. The consideration that every household will supply certain quantity of biomass regularly did not work in most of the projects (World Bank, 2011). It is experienced by one of the authors of this report that in certain villages the issue of elite capture resulted in fragmented social order and disrupted the fuel supply leading to shut down of the project. This disruptions in the fuel availability led to irregular energy services. This further resulted in poor willingness to pay by the communities.

However, it emerged from the discussion with experts that certain course corrections could have been led to success of the programme. Transferring the management from the VEC to the local entrepreneur with adequate inbuilt incentive mechanisms could have worked better. This could have addressed the fuel availability problem, technical management problem as well as payment collection problem.

It is also suggested by stakeholders directly engaged in the project operation and management that a technology neutral approach would be a better approach than only limiting the option to biomass based technologies. It also suggested that institutional failure could have been minimised if SNAs would have been given the power to sanction the projects and implement the project through dedicated project management units (PMUs). Similarly, technical solutions, through is systemic problem, could have been better addressed through creation of robust aftersales services locally.

2.3.2 Project specific case study: Kandhmal Solar Mini-grid Project

1. Background information

TERI has implemented a solar micro-grid project in the Burangia (Village Census Code - 03706500) of Daringbadi Block of Kandhamal District in the province of Odisha, India. The village cluster of Burangia is one of the remote hamlet clusters in the districts. The district Kandhmal of Odisha state of India is also identified as a priority intervention area by many of the national and international development agencies. These hamlets are deprived of electricity since time immemorial and relying on traditional sources of energy for meeting their lighting and other energy requirements. The solar micro-grid project was set up as part of the OASYS Project supported by UK Research council and implemented by TERI, New Delhi, India. The project was part of the demonstration projects of the OASYS project which aimed at finding appropriate local solutions for sustainable rural electricity supply. The solutions were expected to be techno-economically viable, institutionally feasible, socio-politically acceptable and environmentally sound. The larger goal of the project was to demonstrate the benefits of customised technology solutions in tune with the community needs. The project site map is presented below in the Figure (Figure 2.5).

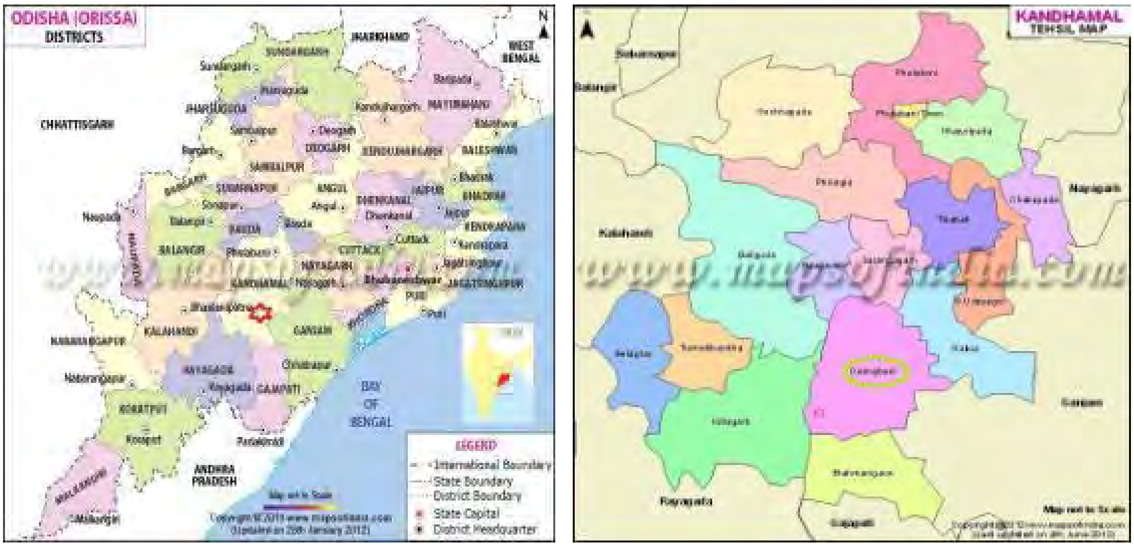

Figure 2.5: Map showing the project location in the Kandhmal district of Odisha

The Burangia hamlet cluster consists of four different hamlets such as Mundasahi, Budulpadi, Jharmunda and Burangia. The cluster of hamlets has a total population of about 300, who are direct beneficiaries of the project and 700 people around the village cluster are indirect beneficiaries. The demographic details of the Burangia village cluster is depicted in the Table below (Table 2.2).

Name of hamlet	Mundasahi	Budulpadi	Jharmunda	Burangia
Revenue Village	Burangia	Burangia	Burangia	Burangia
Block	Daringbadi	Daringbadi	Daringbadi	Daringbadi
Total HHs	8	200	40	32
Total population	46	800	142	178

Table 2.2: Demographic details of the cluster of hamlets

2. Rationale of the project

The project is very different in the sense that it was a joint effort by sponsoring agency, project implementing agency (PIA) and local administration. The inclusion of local administration as an important stakeholder in the project is very unusual in the domain of off-grid or decentralised energy interventions in India and hence adds to the uniqueness. From the research angle, it is fascinating to explore various facets of project development, project operation and management and project impacts of this multi-stakeholder managed project. The project objective was to showcase the crucial importance of local administration in the long-term sustainability of the project. This motivated to consider this as an important case study for the report.

3. Methodology

Primary survey was conducted to elicit information related to various aspects of project management and operation. Two times visit was made to the project site to understand the appreciate the multiple dimensions of the project – starting from the initiation and conceptualisation state till the operation of the project. The survey was done at two different levels. One level of survey was carried out at the stakeholder's levels such as interviewing the local NGO engaged in the project activities, since the beginning, meeting with VEC members, interviewing local technician, and officials of local administration. The second level survey was done at household level to elicit information related to use of energy, about their future aspirations from the projects, benefits derived from the project, and problems encountered.

4. Key characteristics of the project

As mentioned above, one of the key characteristics of the project is the participation of the local administration in the formulation and funding of the project. This is very unique in the domain of the off-grid energy interventions in India.

Second most salient feature of this project is about the project site. The project is absolutely located in a remote and far off-area, disconnected from the mainstream development. A river completely disconnects the project site from the mainstream development area. In addition, the project district though has been known as priority funding district by both domestic and international donor agencies, these clusters have been completely overlooked by these agencies.

Third feature of this project is its technical aspect i.e. it is a 18kW AC mini-grid project, set up to demonstrate the viability of a business model developed as part of the OASYS project. Everything has been automated to as to minimise the human intervention.

In addition, the project also aimed at creating local capacity through regular training and capacity building exercises. Regular trainings have been provided and VEC meets twice a month to discuss the key issues related to the project.

5. Technology

The designed capacity of the project is 18 kW PV technology. The project was designed as a mini-grid. The public distribution network (PDN) is laid down to distribute electricity to the chosen hamlets.

Along with this 2nos. 9 Kva inverter (Grid Tied), and 120 V, 600 Ah battery bank are also deployed as part of the project. System has been made automated to minimise the human intervention.

6. Energy service

The energy service consists of provision of two light points and one mobile phone charging point per household. Along with this, some provisions are also made to provide street lights in the chosen hamlets. The plant which is installed near to the primary school of the village also provides electricity to the school.

It emerged from the discussion that the electricity provisioning has generated multiple benefits. The electrification of the school has been very useful. They can now run computers for their official works. Fans have been installed in the classrooms and have been very helpful in summer time.

Households have been benefiting in terms of larger working hours, children's are able to study during evening. The use of Kerosene oil has been reduced substantially and have generated huge amount of carbon benefits. Women have been benefitting in terms of getting extra hours to do their house chores.

7. Delivery model

One of the initial exercises in the process of project implementation is the mobilisation of the community and formation of VEC. The study report on the project reveals that as an initial step, Gram Sabha was conducted in 19th March 2015 to ascertain the energy demand and to assess the existing livelihood patterns of the community. Along with this a village energy committee was formed as a custodian of the project and to take care of the operation and management of the project. Officials of the local administration was invited to be present in the Gram Sabha meeting and agreed to support financially to the project by constructing the house for the project installation. A resolution was passed at the first Gram Sabha meeting to form the VEC. The project site was unanimously identified by the Gram Sabha. A plot of land adjacent to the village school was identified to put up the solar PV plant.

It was decided during the meeting that at least two members will be chosen from each hamlet/*sahi* of the project village. The VEC was named as '***Chakadola Urja Committee***'.

A joint bank account was also opened in the nearby post office to deal with the monetary transaction of the project. Four members from the VEC were selected as office bearers such as President, Vice-president, Secretary, and Vice-secretary. In addition to this a local energy entrepreneur was involved in the execution of the project. The energy entrepreneur was involved in the formation of VEC, and in laying down the PDN and setting up of the power station. VEC was responsible for the identification of the operators for the power plant. Purchase order to solar power plants and distribution network was done in a very transparent manner. Two different vendors were chosen from a list of vendors to install the project and lay down the PDN line respectively. The project was installed on 28th March 2015 while the PDN was laid down in 5th April 2015. Delivery model consists of paying one time charge known as connection fee and a monthly rental for the use of energy.

8. Financial structure

In order to ensure the financial sustainability of the project, a onetime connection charge of Rs 500 was charged per household which was deposited in a fund called maintenance fund. The fund was kept to meet the unforeseen maintenance expenditure. In addition to the above, a monthly tariff of about INR 30 (approximately USD 0.5) is charged per household for using two light points and one mobile phone. The money collected through the monthly charge is used to pay the operators salary and a part of it is kept aside to meet the battery replacement costs at the end of the fifth year.

9. Driving factors

It was observed during both the visits that the project has been running very successfully for last one year. As mentioned above, one of the major contributing factors for success of the project is the involvement of multi-stakeholders including the local administration. The success of the project is also linked to the strong institutional support to the project. An active VEC is formed to deal with the day-do-day affairs of the project management and operation, on the other hand, local administration is engaged to look at the larger issues of project operation and management. It is evident from the survey that monthly VEC meetings were conducted to ensure that the project is running smoothly without any major hurdle. In addition, the presence of local NGO also acts as lubricator for the success of the project management and operation.

On the technology front, the installation of the automated systems has minimised the human intervention and hence reduced the number of technical glitches. Both the solar PV and inverters and battery banks were provided by reputed makes to ensure their long-term sustainability. A comprehensive maintenance warranty was also signed with the technology partners to take care of unforeseen technological damages. In order to ensure the long life of the battery, battery management system was incorporated in the power plant to have control of the battery discharge and hence longer battery life. Agreement was also made with the technology provider for aftersales maintenance plan, which consists of 1) rectification of faults during the warranty period, 2) building local technical capacities in order to self-sustain the project. As a capacity building effort of the project, regular refresher trainings were also arranged in coordination with the vendor, TERI and VEC to improve the technical skills of the local operator. All these have contributed a lot to the technical aspects of the project development.

Similarly operational sustainability of the project can be observed from the inbuilt process. In addition to the one-time connection fee, a monthly tariff of INR 30 (approximately around 0.5 USD) per household for two light points and one mobile phone charging is charged to meet the operator's salary and to meet the battery replacement cost regular O & M expenses. This has contributed to the financial sustainability of the project operation and management.

However, despite several success elements, the project also has encountered some challenge in several aspects. One of the major challenges was with the payment of one time connection charge. Given the poor affordability of the beneficiaries, it becomes difficult for them to pay this one time connection charge. In addition, it was also observed that on maintenance front, the PDN technical partner is required to do the maintenance again, which has not been done.

3. Situation analysis of Thailand’s decentralised energy sector

3.1 Section I. Background Research

3.1.1 Country profile

Thailand, officially known as Kingdom of Thailand, is the second largest economy in Southeast Asia. It is the 51st largest country by total area while 20th largest by its population in the world. Located in South-East Asia and covering the total area of 513,115 sq. KMs, Thailand is surrounded by countries such as Myanmar (Burma), Cambodia, Laos and Malaysia. It also shares its land border with the Andaman Sea in the west and the Gulf of Thailand in the South. According to World Bank data, the total Population of Thailand is 67.73 Million in 2014, out of which the female population is about 51% and rest are males. Majority of the population are Thai constituting about 95.9% while other ethnic groups are very few viz. Burmese 2 %, other 1.3 %, unspecified 0.9 %.

With over 80% of the country's 7.3 million poor living in rural areas (as of 2013), Some regions—particularly the North and Northeast—and some ethnic groups lag greatly behind others, and the benefits of economic success have not been shared equally, especially between Bangkok, Thailand’s largest urban area, and the rest of the country. Thus, Poverty has primarily been a rural phenomenon in Thailand (World Bank, 2015). However, Thailand has made significant progress in last four decades to uplift itself from the low level income group to upper income group. Gross Domestic Product (GDP Current) stands at USD 373.80 Billion while the GDP per capita stands at USD 5519.36 in 2014. Industry and Service sector in Thailand have kept the economy sailing even through the toughest times. Industry and services are the major contributing sector in the GDP comprising almost 90% of it: 42.04% is contributed by Industry and 46.33% by Service sector in Thailand. Agricultural sector stands at a meager 11.64% of GDP in 2014.

As per the World Bank data, the percentage of urban population out of total population in 2014 is 49.17% and the rate of its growth is 2.94%.

Thailand is divided into 4 regions namely Central, Northeastern, Northern and Southern[2] and 76 provinces. The national government of Thailand is divided into 3 types: Central Government (which includes ministries, bureaus and departments), Provincial government (which includes provinces and districts) and local government (Bangkok, Pattaya City). Bangkok and Pattaya are the two specially governed districts. However, energy policies are dealt centrally. Such policies are drafted/reviewed by Energy Policy and Planning office (EPPO) and follow through Ministry of Energy, National Energy Policy Council (NEPC) and then to the Cabinet. Moreover, implementation of such energy projects also takes place at the provincial level.

In an ADB's Energy Outlook considering Business-as-usual (BAU) case, Thailand's primary energy demand is projected to accelerate at 2.2% rising from 117,400 ktoe in 2010 to 204,800 ktoe in 2035.

3.1.2 Energy resource and technologies

In Thailand, the primary energy supply consists of coal & its products, crude oil & natural gas liquids, condensate, natural gas, petroleum products, electricity, renewable energy, and biofuels. Moreover, decentralized and grid connected renewable energy in Thailand has made a rapidly growing contribution to the country's energy supply and it should continue in order to fulfil the 25% target in the country. An analytical study reveals that with the penetration of Distributed Generation (DG) in the system regarding its potential and power development plan of Thailand (PDP 2007), DG share will increase from 2% (1,759 MW) in 2007 to 17% (12,282 MW) by the year 2026 .

In Thailand, the total primary energy supply is 134,308 ktoe in 2013. Out of total domestic production for the primary energy supply in 2013, the natural gas accounted for 46.63%, coal and its products 5.71%, Crude Oil & Natural Gas Liquids (NGL) 9.43%, condensate 5.78%, Biofuels 2.06%, the renewable 12.79% and the traditional renewable energy forms 17.61%. The renewable energy resources are significantly considered to achieve the alternate energy targets in Thailand. Moreover, Biomass seems to be the highest contributor among all the renewable energy resources, be it in terms of electricity or heat. Out of total 1,341 ktoe (3788 MW) of electricity from the renewables in 2013, biomass alone contributed 1,039 ktoe (2320.78 MW) electricity whereas in context of heat consumption, 4694 ktoe out of 5279 ktoe is supplied by biomass. Other renewables sources such are solar, wind, small hydro and biogas add much smaller proportion than conventional energy used.

	2010	*2013*
Solar	**48.6**	**823.5**
Wind	**5.6**	**222.7**
Small Hydro	**58.9**	**108.8**
Biomass	**1650.2**	**2320.8**
Biogas	**103.4**	**265.7**
MSW	**13.1**	**47.5**

Table 3.1: Installed capacity of alternative energy power plants in Thailand (MW)

In context of renewables, Table 3.1 shows that as of 2013, 92 ktoe (823.46 MW) of solar energy has been installed. A SHS for rural electrification and roof-top solar PV for meeting urban electricity demand have been interesting renewable decentralised energy systems in Thailand. Moreover, Solar PV has been used at rural community school and national parks for electricity. Similarly, potential wind power sources are located in the Gulf of Thailand and as of 2013, about 26 ktoe (223 MW) of wind energy has been installed. As a part of island electrification where there is no grid-connection available, 80 hybrid (Solar and Wind) power generation systems have been implemented in Paluai Island in Surat Thani Province with 500W each from wind and 300 W each from solar, thus making power generation stable both in day and time. Similarly, hydropower too has a good potential, however, these are difficult to exploit due to environmental impacts on the resource area. A small hydropower installed as of 2013 is about 28 ktoe (109 MW), more of such would add to the DE in Thailand. The use of solar, wind, plantation-based biomass, MSW and biogas are considered for power generation, while agricultural residues are considered for cogeneration and residential cooking in the future (Shrestha et al, 2016).

3.1.3 Energy services and requirements

As per Ministry of Energy's fact and figures 2013, more than 70 % of the total energy is consumed in transportation and industrial sectors. The agriculture sector accounted for only 5.2 % whereas 15.1 % and 7.7 % are consumed by residential and commercial sector respectively in 2013.

Figure below (Figure 3.1) shows that the forecasted total energy demands in 2025 considering Business-as –Usual (BAU) scenario. It clearly reveals that the amount of energy demand for Industrial and transportation sector by 2025 is likely to be more than doubled, while commercial and agricultural sector is expected to demand similar amount of energy consumed in 2015. However, the percentage consumption out of the total energy consumed is expected to decrease for both these sectors. Compared to 2013, the percentage change is negative for residential sector in 2025.

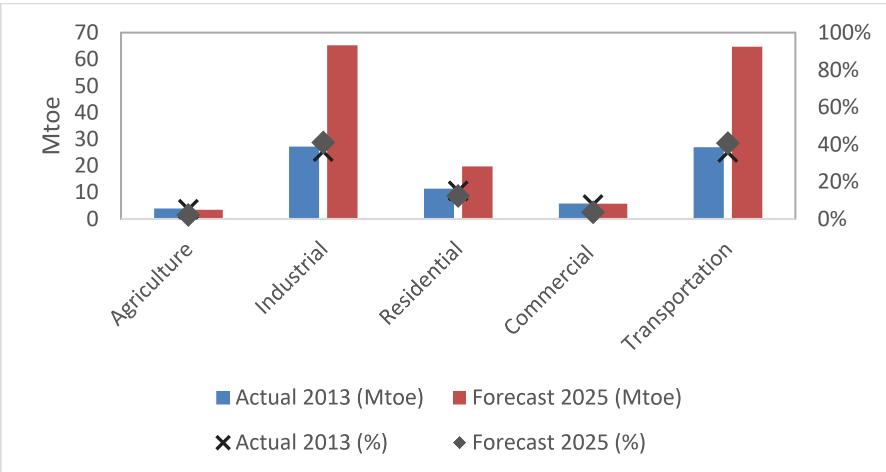

Figure 3.1: Energy consumption and demand forecast as per economic sector

Considering the ever-increasing demand, Thailand needs to explore all the alternatives possible to secure the energy requirements. In doing so, decentralized energy becomes paramount importance which not only helps make the system more efficient by utilizing the waste heat through cogeneration but also promotes renewable energy thus thereby reducing the transmission losses and the GHG emission. Moreover, the government aims to improve the efficiency and use energy-efficient products to lower the consumption of energy.

3.1.4 State of decentralized energy systems

The inherent problems of the Thailand's energy systems such as problems associated with energy pricing, international competition for energy resources, current energy mix and it's consequent impact on the environment and climate change necessitate the need for alternative options to address the potential problems in addition to fulfilling the future demands. This is where the importance of decentralised generation becomes paramount. As per Power Development Plan (PDP) (2010-2030), cogeneration has been recognized as an efficient electricity generation (Ministry of Energy, 2012), which forms an essential element in Decentralized Energy. The revised PDP anticipates the total install capacity during 2012-2030 to be 6746 MW, which also includes cogeneration from SPP and VSPP(Ministry of Energy, 2012).

Decentralized energy system refers to systems which necessitate locating the energy production facilities closer to the energy consumption site. **World Alliance for Decentralized Energy (WADE)** defines **Decentralized Energy (DE)** as: "Electricity production at or near the point of use, irrespective of size, technology or fuel used- both off-grid and on-grid."

Decentralized energy technologies classified in the WADE model for Thailand's power generation are coal CHP, oil CHP, gas CHP, biomass, biogas, solar PV, wind, small-hydro and Waste to Energy (WtE). Decentralized energy system in Thailand has been considered both in terms of on-grid and off-grid system. The on-grid system is both the renewable energy systems (Net Metering) and the coal powered plant, where cogeneration is very vital in the latter and additionally the excess energy from SPP generators. Micro/Mini grids have been established in various parts of different provinces where direct national grids have not reached. Smart Grids have been considered an evolving technology in DE system. The off-grid system in Thailand is either diesel power generator or renewable energy system. Electrification of rural villages and islands are largely done by renewable energy systems. Solar home system (SHS) stands as a successful DE intervention in Thailand. So far this report is concerned, the scope of our study is limited to Net-Metering and financial intervention for its success, Cogeneration in fossil fuelled power plants, decentralized renewable energy systems (such as micro-hydro, Solar PV, wind and biomass) and in particular, the Solar Home System (SHS).

There is tremendous scope for decentralised energy/ CHP and cooling in Thailand.It is estimated that projected share of distributed generation to 17% by 2026, would result in significant savings on primary energy 84.3 TWh/year (11%), emissions reduction (NOx, SO2, PM10, CO2) 40 Mton (17%), capital cost savings US$ 1.42 billion (3%), and mostly in a reduction of required additional capacity of around 4,955 MW (6%).

The history of Decentralized Energy in Thailand can be traced back from 1950s where the sugar industry employed cogeneration. Over time, the country essentially relied on grid based electrification program and used off-grid technologies in limited scale. Micro-hydro system were introduced in early 1980s and used in Northern rural areas in Thailand. However, Thailand's foray into distribution generation/ decentralized energy began in 1992 when the national energy policy was revised to allow private participation in power-sector investment, providing opportunities for them to venture into decentralised energy sector. The NEPC's approval to include the SPPs in power investment brought an opportunity for DE to flourish in the country against the nation's centralized generation concept. The regulations allowed grid interconnection of small-scale renewable energy and fossil-fuel fired combined heat and power (CHP) generators up to 90 Megawatts (MW) in size. Within a span of 4 years, this Small Power Producer (SPP) program has contributed nearly 1000 MW of renewable energy capacity, which is significant considering Thailand's total peak load in 2006 was just over 21000 MW (Ministry of Energy, 2012).

Furthermore, In 2002 Thailand became the first developing country to adopt net metering regulations (known in Thailand as Very Small Power Producer (VSPP) Program) that paved a path for even smaller renewable generators under one megawatt in size. The first four years was successful enough to add 13 MW to the grid. The law was later revised to qualify projects under 10 MW in size. The Net Metering regulation laid sufficient ground for intensive decentralized energy development in Thailand as integration of small scale decentralized renewable energy to national grid was made possible through this program. The "adder" made the program more lucrative to investors. As solar energy was given priority earlier and higher tariffs were set, it was changed to a fixed FiT program in 2010 and the focus shifted to solar Rooftop system only.

3.1.5 Variants of decentralized energy systems

The power demand is continuing to increase and therefore, to meet this, the government of Thailand has been enhancing power generation capacity. As part of this effort, power sector has been designated as priority to lure vigorous private investment. IPPs, SPPs and VSPPs have been using private funds and international loans to build power projects. For instance, Japan Bank for International Co-operation (JIBC) approved a loan of US $ 640 Million to Ratchaburi Power Company Limited (RPCL) to construct and operate 1400 MW combined cycle gas turbine[3]. Similarly, King Mongkut's University of Technology Thonburi (KMUTT) constructed the first starch biogas system in 2000 partly funded by government subsidies. EPPO funded 25 % of investment costs. In 2003, EPPO also launched a pilot demonstration of biogas in the starch industry in 9 factories, which received grants from ENCON fund through agencies including DEDE and Chiang Mai University. The subsidy amounted to 30 % total project costs while remaining is funded by factories. The project was estimated to displace 22 million liters of heavy fuel oil (Siteur, 2012). This clearly reflects sufficient government support for decentralized generation.

Some projects like Khorat Waste to Energy located at Sanguan wongse Industries operates on a Build-Own-Operate-Transfer (BOOT) model, providing SWI savings of 20% on its energy expenses, at no risk. Under the BOOT agreement, SWI committed to purchase all gas and electricity supplied by KWTE. Tariffs are based on 80 % of fuel prices adjusted on monthly basis. The provision is such that if the supplier cannot supply sufficient energy, the off-taker can revert to the grid and fuel oil for balancing their needs (Siteur, 2012).

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[3] http://www.jica.go.jp/english/news/jbic_archive/autocontents/english/news/2005/000090/index.html Accessed on 2015.05.05

It is imperative to mention that Thailand was among the first countries in Asia to introduce incentive policies for electricity generation from renewable source of energy. In 2006, Thailand's state owned electricity distributors offered to buy electricity from renewable energy producers under power purchase agreements (PPAs) in which an adder rate (based on the technology used) was payable on top of the prevailing wholesale price of electricity. It can be observed in the rapid growth of solar energy in different areas throughout the country. The "Adder", a feed-in premium, guarantees higher rates for renewable energy, making the investments profitable. Furthermore, a sophisticated feed-in tariff (FiT) is introduced to control cost, while continuing to enabling suitable environment for investments in renewable energy. In 2010, NEPC approved transitioning from adder to Feed-n-Tariff (FiT), in which a fixed amount per kWhr is paid during the life of the PPA. The Energy Regulatory Commission (ERC) ordered Thailand's state owned electricity distributors (PEA, MEA and EGAT), to cease offering PPAs to power producers generating less than 10 MW (VSPPs) and instead to issue PPAs based on the ERC's FiT subsidy program. The FiT PPAs are for a 20 year term for all eligible forms of renewable energy with the exception of land fill, for which a ten year PPA is offered.

3.2 Section II: Assessment of country specific policy, regulatory and other incentives

The following section reviews policies, regulations, incentive framework governing the decentralised energy sector in Thailand. In addition, the section also maps the institutional framework supporting the decentralised energy systems in the country. The key policies promoting decentralised energy in the country are Alternate Energy Development Plans (AEDP), Power Development Plans (PDP) and Energy Efficiency Development Plan (EEDP). These plans intend to promote renewable energy and thereby decentralised energy systems in the country, which are embedded in the renewable energy system development in the country. Most important schemes in the arena of decentralised energy systems are the SPPs and VSPPs.

The policies related to energy, including renewable energy policies are formulated by the Ministry of Energy (MoE), Government of Thailand. Energy Policy and Planning Office (EPPO), which is part of Ministry of Energy oversees all aspects of the country's energy policy formulation in all fields of energy such as oil, natural gas, and power sectors. National Economic and Social Development Board (NESDB) is entrusted to manage the large energy infrastructure projects along with the planning of future energy infrastructure projects. In addition, Energy Regulatory Commission (ERC), created through the Energy Industry Act, 2007, acts as an independent regulatory agency for the sector. ERC's key responsibilities are monitoring the energy market, electricity tariff regulation, and licensing and dispute settlement. Power Development Fund which funds the subsidy for renewable and environment friendly energy systems is also managed by the ERC.

Since, decentarlised energy systems in case of Thailand is embedded with the grid based electricity systems, it is essential to understand the Thailand's electricity structure (Figure 3.2), which shows stakeholders from generation to the end consumers. The state-owned Electricity Generating Authority of Thailand (EGAT), which was established in 1968 controls most of the power generation and the country's transmission completely. EGAT purchases electricity from public and private producers and sells it to unbundled distribution companies and few large direct customers. Provincial Electricity Authority (PEA) is held responsible for electrification of the provinces including the rural electrification. However, electric power to the Bangkok Metropolitan area and two adjoining provinces is distributed by the Metropolitan Electricity Authority (MEA).

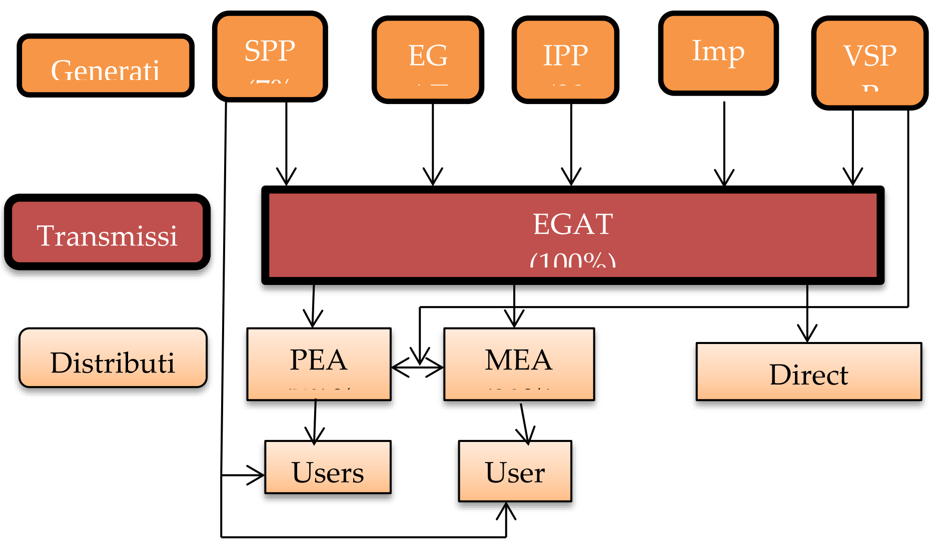

Figure 3.2: Structure of Thailand's Electricity Sector (Tongsopit, 2013)

Contextualising this to the decentralised energy development in the country, it can be clearly inferred from the above Figure that SPP and VSPP – the major players in the field of decentralised energy development in the country, not only produces electricity and sells them to EGAT for transmission but also distributes electricity to direct customers/ users. Such production and distribution occurs either at rural community where national grid has not reached citing low demands of electricity or at places where SPP generates more electricity than allowed (which it sells to the community/ industry nearby directly).

The institutional structure involves multiple players connected to each other. These players are placed at different levels such as Federal level, provincial level and also at local level. One of the major actors is private producers. One set of private producers are known as independent power producers. The year 1992 saw an era of liberalization in Thailand's Electricity sector with the introduction of IPPs. Of the total electricity generation capacity in 2014, about 38% is supplied by IPPs alone. Most of the IPPs use natural gas as fuel for a combined cycle power plant4, which works on the principle of cogeneration. They also form part of the decentralized energy systems.

Another set of private players are small power producers (SPPs) producing CHP and renewable energy, through the decentralized energy mode. SPP generators sell electricity to EGAT, which gets distributed over to end users through PEA and MEA. SPPs contribution towards decentralized energy comes into effect when SPPs produce electricity in excess of upper limit (i.e. more than 90 MW), which is either used for self-consumption or sold directly to factories or buildings nearby, in addition to selling steam generated through waste heat to the nearby industrial state. As of April 2008, SPP's generating capacity was 3877 MW out of which 2286 MW of electricity is connected to grid whereas the remaining is sold to users located nearby. SPPs are generally 10 MW or

[4] Derived from IPPS(March 2015) table, accessed from: *www.egat.co.th/en/images/statistics/.../eng-private-**power**-plant-0257.pdf*

larger and limited to export a maximum of 90 MW. SPP generators above 8 MW must connect to high voltage (69 kV or 115 kV) lines.

Yet, another set of private decentralised energy generators are known as Very Small Power Producer Programme (VSPP). The programme on VSPP was intended encourage producers producing below 1 MW, which is not considered under SPP programme. The introduction of this new VSPP was aimed at power generation through non-conventional energy, making use of domestic resources efficiently, and to provide electricity access to the rural areas with sufficient community participation. Later on, the government revised the capacity from VSPP to 10 MW. The new VSPP regulations also allowed fossil fueled CHP. The VSPP program was developed as a Net Metering Regulation in Thailand.

There are also exist some non-profit organisations supporting the development of renewable energy in general and decentralised energy in particular. Non-Profit Organizations. For instance, the Border Green Energy Team (BGET), provides hands-on solar and micro-hydro training for villages on both sides of the Thai/Burma border5. This NGOs operates more at the provincial level working closely with the rural community.

Similarly, WADE (World Alliance for Decentralized Energy) Thai is another non-profit organization inclined towards development of high efficiency cogeneration, onsite power and decentralized energy systems that deliver substantial economic and environmental benefits. Recent activities show WADE Thai being involved in Smart Grid Technology development in Thailand. Moreover, this organization operates at the national scale and helps the government to carry out decentralized energy activities smoothly.

In order to promote decentralised energy in Thailand, various incentives are provided through various policy provisions. One such is related to the Thailand Energy Conservation Promotion Act (ENCON Act), enacted in 1992. Department of Alternative Energy Development and Efficiency (DEDE) is the main implementing agency under this

[5] Adapted from www.palangthai.org

act. The Act requires that designated factories and buildings conduct energy audits and submit energy conservation plans every three years.

As an offshoot of this Act, the government also established the Energy Conservation Promotion Fund (ENCON Fund), sourcing funds from the Petroleum Fund, This fund was created for providing financial support for the implementation of energy conservation activities such as energy efficiency (EE) improvement, renewable energy (RE) and alternative energy development, R & D Projects, human resources development, public education and campaigns.

Year	Incentives	Description
2002	**30 % Subsidy Program**	- Supported designated factories and buildings to implement Energy Efficiency (EE) projects. - DEDE covered 30 % of the capital costs
2003	**Energy Efficiency Revolving Fund (EERF)**	- Provided low interests loans to local banks for on-lending to clients. - During 2003-2011, 294 projects such as factories and buildings were implemented.
2006	**Tax Incentives**	- Included exemption of import duties for energy efficiency (EE) and renewable energy (RE) equipment - All the small scale renewable energy generators qualify for this incentive.
2006	**Adder program**	- An adder rate was paid as an incentive on top of the prevailing wholesale price of electricity. - depends on the technology used - It was initially as high as 0.23 US$ per kWhr for solar energy.
2008	**ESCO Fund**	- Supported equity investment, ESCO venture capital, equipment leasing, & technical assistance
2013	**FiT**	- Premium-price feed-in tariff, or Adder, was offered for solar power

Table 3.2: Incentives for decentralized energy developments

Thailand has specified its long-term energy planning in the Power Development Plan (PDP) 2012-2030, which was later revised in 2014 to PDP (2015-2036). The new plan is based on three principles, energy security, economy and ecology. The new PDP aims at installing an additional capacity of 57,400 MW by the end of 2036, totalling the country's electricity capacity at 70,410 MW in 21 years from 2015. It focuses mainly on the increase of "cleaner fuels" and 'less reliance on natural gas'.

The Alternative Energy Development Plan (AEDP) recently being revised, in 2014, targets an installed capacity of alternative energy at 19,635 MW in 2036 – from around 7,279 MW in 2014. AEDP 2015 was revised focusing on power generation from waste, biogas, biomass as priority, as well as competitive bidding as a selection process for FIT application instead of first-come first-serve and to increase renewable energy consumption from 8% to 20% of final energy consumption in 2036.

Given that the renewable energy to be tapped including the small scale, the Thai government in 2007 also brought changes to the policy to promote energy efficiency and renewable energy projects including the decentralized energy projects relating to SPPs and VSPPs. The SPP and VSPP regulations were amended; changes were made to the criteria for qualifying facility, calculation of the avoided cost, and interconnection requirements, making them more friendly and practical. Cogeneration was included within the VSPP program and sale from a facility of up to 10 MW while sale of 10-90 MW for SPP would come. SPP cogeneration facilities were allowed to sell power to the grid under long term contracts again, and in the initial phase EGAT has established a target to buy another 1,600 MW of power from new cogeneration facilities under long term contracts. SPPs and VSPPs using renewable energy were granted higher tariff by providing an "adder" on top of the normal tariff for 7-10 years from the Commercial Operation Date (COD) for proposals submitted before the end of 2008. In the case of biomass SPP, the "adder" was determined through a competitive bidding system where the government issued a solicitation for 300 MW on 1 May 2007. A special "adder" for SPPs/VSPPs were established in the 3 Southern most provinces (Yala, Pattani and Narathivath) of 1.50 baht/kWh for wind and solar energy, and 1.00 baht/kWh for other types of renewable energy to compensate for the political risk from the unrest. Financial incentives through soft loans and investment subsidies were expanded in amount and coverage for selected types of renewable energy projects, in particular biogas in pig farms and factories producing tapioca starch, palm oil, rubber sheet, ethanol and other types of agro-industry, municipal wastes, and micro-hydro.

Similarly, on 23 August 2011, Prime Minister of Thailand laid down policies to drive energy sector, reinforce the energy security, and ensure fairness and support R & D. Emphasis was laid on small scale decentralized energy systems with the expectation that it would generate energy surplus and allow export of such energy.

Year	Policy and Related Department	Description
1992	SPP Regulation	- Applies to both Combined Heat and Power (CHP) (generally using natural gas or coal) and renewable energy. - **Each generator can export up to 90 MW.** In order to qualify, generators had to: *1) utilize 10% of waste steam energy* *2) Achieve a combined overall average efficiency (electrical plus thermal) of at least 45%.*
1992	Energy Conservation Programme	- provides financial support to for new and renewable energy technologies
2002	VSPP Regulations	- allows renewable energy producers up to 1 MW to connect to the grid and offset their consumption at retail rates.
2004	DEDE's strategic plan of 8 % Renewable energy	- **targeted to increase the renewable energy share of commercial primary energy to 8% by 2011**. One of its objective is to - promote co-generation and in heating/cooling systems,
2004	PEA's SHS	- To **provide electricity to 1% deprived rural households** through standalone SHS mode
2006	Upgradation of VSPP Regulations	- Can invest in clean fossil fuel fired CHP. - Net export threshold is expanded tenfold to 10 MW. - A per kWh subsidy called "adder" was added
2009	Renewable Energy Development Plan (REDP) 2008-2002	- Aimed at **bringing RE to 20.3% of Thailand's total energy mix by 2022,**
2012	Alternate Energy Development Plan 2011-2021	- Aimed at increasing alternative energy consumption to 25% by 2021 This promote rural electrification in
2012	Third revision of the Power Development Plan (PDP 2010)	- Targets that by 2030, 6,476 MW of Cogeneration, 25451 MW of Combined Cycle Power Plants and 9481 MW of renewable energy power will be set up
2015	Alternative Energy Development Plan (AEDP 2015-2036)	- targets an installed capacity of alternative energy at 19,635 MW in 2036 – from currently 7,279 MW in 2014.

Table 3.3: Policies related to decentralized energy

Two major programmes requires special attention. Thailand's Adder Program and Feed in Tariff (Fit) Program are the two programs which intervened successfully for promotion of development of small scale decentralized energy in the country. These programs act as incentives for SPP and VSPP, therefore these are separately discussed as under:

I. Thailand's Adder Program

Thailand's adder program gives incentives for private investors to invest in small scale renewable energy projects, by guaranteeing attractive power purchasing rates. Eligible participants enter into long-term contracts with the local utility to sell renewable electricity at a pre-specified tariff for a pre-specified period of time.

The program is implemented through Thailand's three electric utilities: EGAT, MEA, and PEA. The Adder rates are distinguished by technology type, installed capacity, contracted capacity, and project location. VSPPs and SPPs that utilize solar, wind, biomass, hydro and waste energy are eligible to participate. The rate structure since 2007 is paid on top of the utilities' avoided cost. In addition, there are "additional" adders paid to renewable energy generators of three southernmost provinces, viz. Yala, Pattani and Narathiwat, which have experienced political unrest and off-grid areas. Once the project commences operation and starts selling electricity to the grid, the adder is paid for 10 years (wind and solar projects) or 7 years (other renewables).

II. Feed in Tariffs (FiT) Program

For small scale decentralized energy, the initial cost is high and the producer become less competitive in the market. Therefore, schemes like adder stands as motivating factor and compensate the high initial cost by a bit higher tariffs. However, the adder rate payable depended on the technology used and was as high as 8 Baht/kWh for solar energy. The National Energy Policy Commission (NEPC) has been to progressively upgrade to a "Feed-in Tariff (FiT) from the adder rate payment structures. Contrary to adder, a fixed amount per unit is paid in FiT during the PPA's life. A new competitive bidding method has been announced by NEPC for any future applications for VSPP PPAs. Thus, ERC has ordered PEA, MEA and EGAT to cease offering PPAs for generators producing less than

10 MW (VSPPs) and instead strictly consider ERC's FiT subsidy program to issue PPAs. However, some application for PPAs which were lodged before ERC's announcement will still be eligible for an adder rate PPA.

The ERC gave an option to VSPPs to convert their existing adder rate PPAs to FiT PPAs (other than solar power producers). FiT PPAs are for 20 year for all eligible form of renewable energy except for landfill which is only 10 years. VSPPs are not eligible for convertibility which have already generated electricity into the grid. However, VSPP projects for wind, water to energy or hydropower plants has some exception based on some criteria.

However, strict regulations should exist to keep the investors motivated. Any unusual planning may result in interruptions to such support thus, creating a sense of negativity for the program. Similarly, regulations should be enacted so as to create an atmosphere to protect investors from uncertainties. The PPAs should be checked meticulously so that parties do not hoard the projects for resell at the best rate. At the same time, local communities and people should be made aware of climate change and its effects so that project execution for clean decentralized energy becomes easier to acceptance to the community.

3.3 Section III: Case Study Modules

3.3.1 Programme specific case study: Thailand's Adder Program

1. Background information

As highlighted in the previous chapters, Adder program and Solar PV have higher significance in context of decentralized energy in Thailand. Adder program has been successful in bringing small scale renewable energy developments to the mainstream whereas stand-alone solar home system helped Thailand's electrify rural villages.

Both of these aforementioned programs are considered important milestones in Thailand. The adder program operates at the national level which aims to fulfil Thailand's renewable energy target. This program brings together small scale decentralized renewable energy and medium scale renewable system to the national grid with few exceptions. Although the focus of our study is the small scale decentralized renewable energy in the following section, it may not be possible to isolate the decentralized renewable energy in Adder Program from overall renewable energy. Therefore, at instances, renewable energy has been considered to illustrate the whole scenario as decentralized energy forms an essential part of it.

Similarly, solar home system was designed for the rural villages at provincial scale. Provincial Electricity Authority (PEA) was on the forefront to implement this program. This program is a result of need of electrification of rural villages where grid extension could not be considered due to cost and usability factor. This is a stand-alone electrification program and an important decentralized energy intervention in Thailand's history.

The net metering program (also known as VSPP program) is considered one important milestones for a formalized decentralized energy development in Thailand. It was introduced in the year 2002. Thai Government's aggressive move for infusion of renewable energy through both SPP and VSPP introduced Adder program. It acts as an additional pay over a certain Feed-in tariff (FiT).

Following the increase of VSPP limit (to 10 MW) on September 2006, Thai government introduced "adder" program for VSPPs due to which the very small producers would be motivated to invest more to produce more electricity and earn by selling them. The adder rate varied as per the technology used. Moreover, special adder rates was proposed for three southernmost provinces to alleviate the investment risks. However, it was observed that the adders for solar and wind was not up to mark. Therefore, on November 2007, Thai Cabinet approved adjustment in adders for power producers from solar/wind to encourage investment.

2. Rationale

Thailand was the first among the Asian countries to implement the FiTs programme. The main motive behind the adder program was to encourage investment for more decentralized renewable energy. And the encouragement paid-off well as can be witnessed by increase in number of participating VSPPs from 23 in March 2007 to 264 in December 2007.

The “Adder” Policy/program, a program specific policy in Thailand is considered a significant policy for boosting up investment in decentralized small scale renewable energy program and is a best suited example relating to decentralized energy interventions.

3. Methodology

The required information for this case study module are based on secondary sources, basically the published and unpublished paper and various websites, namely Energy Policy and Planning Office (EPPO) and Department of Alternative Energy Development and Efficiency (DEDE) to name a few.

4. Key Characteristics

Introduction of Adder program immediately drew enough attraction of the investors from the very start. By the end of 2008, a total of 1075 applications for 5147 MW of renewable energy were filed to be considered for Adder. This clearly illustrate the program became so attractive that investors were desperate to file an application to secure the adder rate for their respective technology. Solar Adder secured highest number of application, i.e. 471 totalling 2000 MW alone, which was far more than expected as per the REDP target of that time. There was an unprecedented quest for solar adder; it exceeded the government official target of 500 MW which then started to be called as “Solar Gold Rush”. In addition, this program motivated investors of other renewable energy sectors too, namely wind, hydro, waste, biogas and biomass.

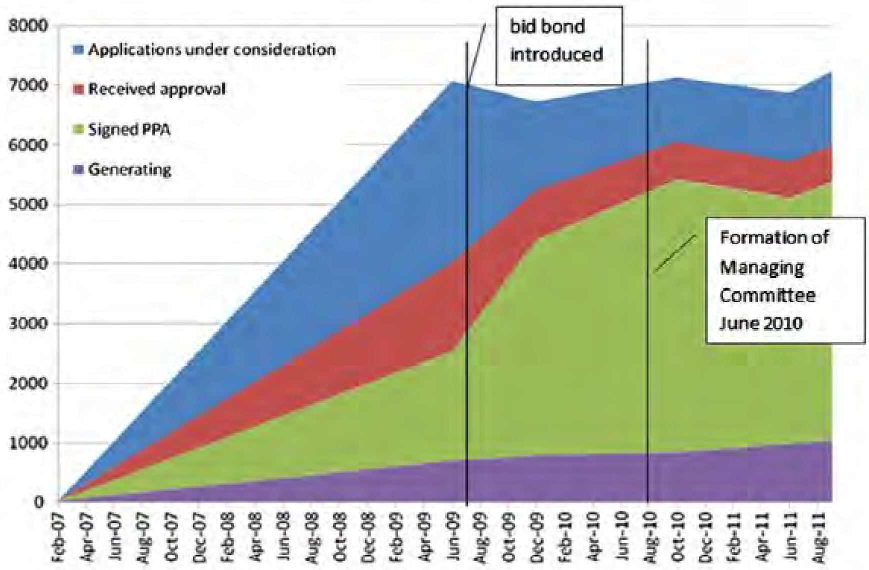

Figure 3.3: MW of Renewable Energy in various stage of development of Feed in tariff program

Source: Tongsopit & Greacen (2013)

Figure 3.3 shows the application filed for the Adder program over different months (from 2007-2011). The program gained its popularity so much that the government had to introduce a bid bond method to consider further application. However, the generation happened at a slower rate than expected. The overall renewable energy is taken into consideration in above Figure as there are such generators which are registered as SPP and receive adder too but they sell part of the electricity to the factories nearby.

5. Technology Used and Energy Services

Adder program has been institutionalized for on-grid technology. This program enables two types of investors, one who proposes to generate less than 10 MW called Very Small Power Producers (VSPPs) and the other, to generate more than 10 MW but less than 90 MW called Small Power Producers (SPPs). The tariff rate depends upon the nature of renewable energy used. The rate for Solar Adder was the highest while it was lowest for biogas and biomass. Special adder rate had been set up for 3 southernmost provinces, viz. Yala, Pattani and Narathiwat, which suffered political unrest and has many off-grid areas. Thus, this reflects that the government was focused to uplift the investment from very small generators as they contribute to the localities nearby.

Solar Adder is further divided into Solar Rooftop PV and Community Ground-mounted. Ground Mounted Solar has a quota of 800 MW while that of Rooftop is 200 MW, out of which 80 MW is allocated to three provinces namely Bangkok, Nonthaburi and Samat Prakarn (40 MW of which is residential and 40 MW is commercial). While the significant power source from solar is solar farm, rooftop solar PV will supply to as many households in urban areas. Moreover, the net metering concept brought a charm for investors to put their money on decentralized renewable developments. Investors even rented house-roofs to construct solar PV and sell it to the MEA. For wind, on-shore technology is used. Electricity is produced from Biomass/Biogas, the sources of which are paddy husk, wood chips, bark, bagasse, etc. Electricity from waste is either done by landfill and digester or by thermal process. Hydro- technology uses the run-off the river scheme.

6. Delivery mechanism

The business model for the adder program can be well explained based on the stakeholders involved: the parties that design, develop and run the business. Figure 9 shows a general model and it is generic to all renewable energy technologies including the decentralized programmes under the adder program. SPP and VSPP are the institutional and individual investors respectively in case of Adder in Thailand. The organizers are usually the local government agencies and it also includes banks/financial institution and lessor group, who help the investors to organize funds and activities for setting up the renewable energy technology. Installers are hired by the investors to set up the technology and at the same time, the organizers' group deploy several authorities to facilitate such installation. The possible sites can be roofs of the houses, open land farms, government buildings, commercial centers and premises of factories/industries.

This program has myriad number of solar roof-top placed on the roofs of the homes in urban area: individual/ institutional investors even consider rented roofs for this purpose. There are solar-farm too, which are under community ground-mounted solar program. Islands are tourist destination, therefore various alternatives of electricity is highly important. Both solar and wind energy are found in various Islands of Thailand.

Biogas and hydro-plants have been constructed near the resource area, both of them are useful in fulfilling rural energy needs.

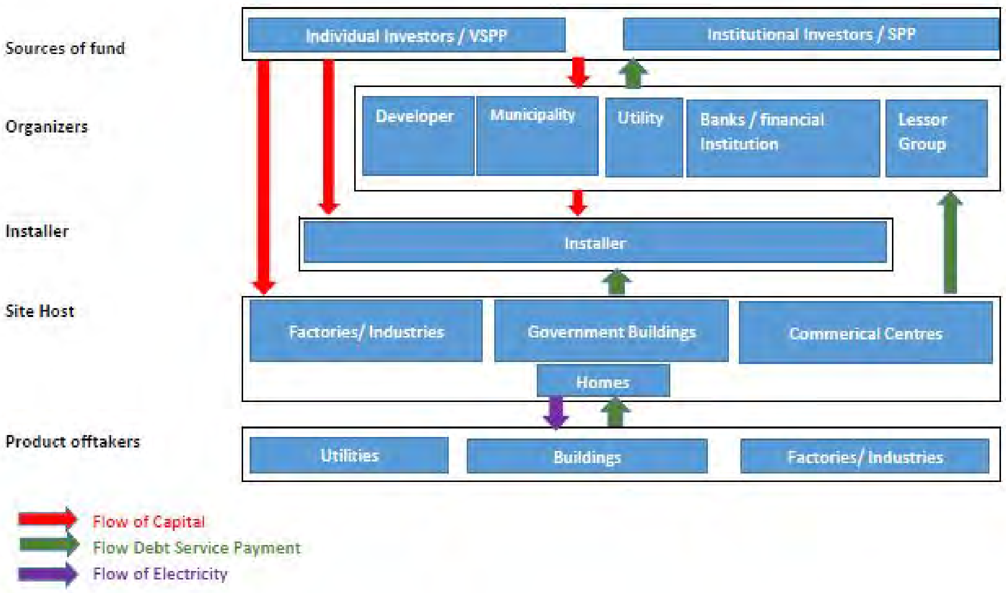

Figure 3.4: Key components and business players in 'Adder Programme'

The concept of decentralized energy is practiced by VSPP for different renewable sources. However, the most popular in Thailand is the roof-top solar PV under the net metering program where adder rates were also applicable, considered one important decentralized program in Thailand. Different financing structure were available for such technology viz. self-financing, utility and public financing, crowd funding, solar service models and other models. Similar financing schemes are also available for other sources under the VSPP program, which motivates investor for decentralized programs.

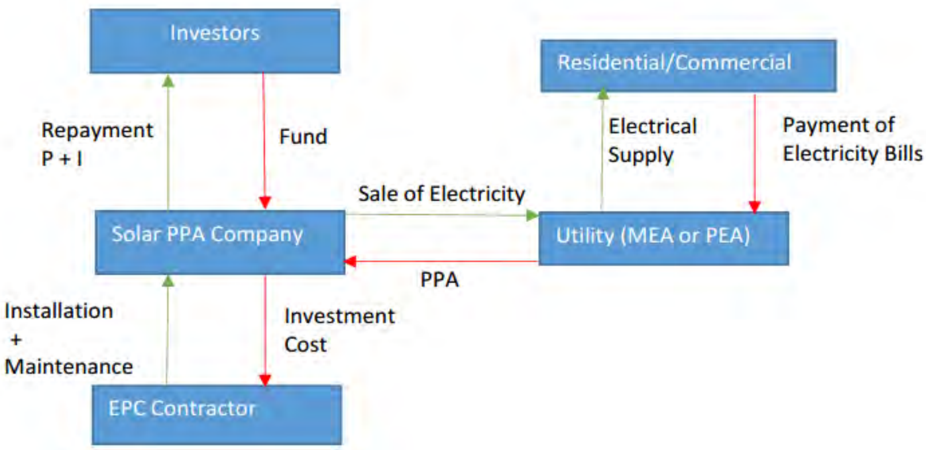

Figure 3.5: Solar roof-top model under 'Adder Program'

Source: Sopitsuda, 2015

Figure 3.5 represents a solar service business model on a power purchase agreement basis. The notion of the solar roof top is to supply clean electricity to urban community so as to fulfil the growing power needs. The investors either through the Solar PPA company or as a registered VSPP makes a power purchase agreement by filing an application through the VSPP program. The EPC (Engineering, Procurement and Construction) contractors usually help make/arrange all the infrastructure, equipment and installation required for power production. The electricity thus produced is sold to the utility office (either PEA or MEA) or EGAT directly, which then supplies to the nearby residential and commercial buildings.

Figure 3.6 represents the key actors involved in planning for Thailand's Adder program and the involved stakeholders. The EPPO, a central agency in the formulation and administration of energy policies and planning for the national sustainability, under the Ministry of Energy (MoE) drafts the program and proposes it to the National Energy Policy Commission (NEPC), which is put to implementation if found suitable. The Energy Regulatory Commission (ERC) plays a vital role setting rules and regulation for the implementation of power policies, including the Adder measure, in Thailand. ERC works within the policy framework established by the National Energy Policy Council (NEPC). The set rules will be passed on to the EGAT and electricity authority, namely MEA and PEA to include additional electricity in the grid produced by VSPPS and SPPs.

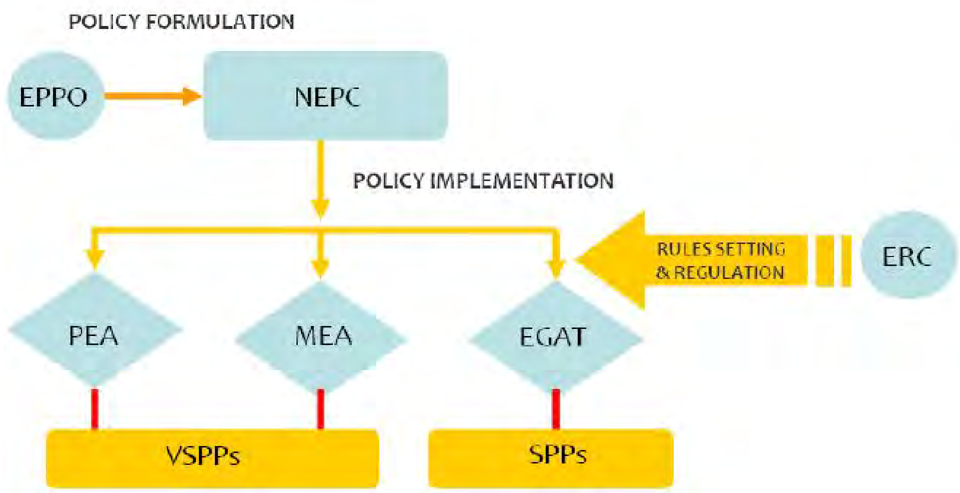

Figure 3.6: Key actors of 'Adder Program'

7. Driving Factors

Adder program that we are considering here is basically for VSPP, although there are SPPs which are producing electricity near the site of consumption. While the focus is more on large power production and also for power producers below 10 MW, it would be challenging to compete with other producers (more than 10 MW) due to economy of scale. The adder program guarantees an "added payment" to such small scale decentralized energy generators to invest in such renewable energy. The tariffs for different renewable energy technologies are the major driving factor for investors. This program has been put to place to achieve following goals in general:

- More renewable energy (to meet the energy targets set by AEDP)
- Participation of private sector and enabling competition market
- Growth of the economy
- Uplifting the rural area of the country
- Utilizing agricultural residues for energy production
- Fuel diversification
- Pollution reduction by converting waste to energy

The foremost thing which acted as a strong driver is the pull strategy of Thai Government to attract investors. The investors, without such strategy, would have to go approach the EGAT by themselves and request for PPA which would have been very less after negotiation compared to what is offered in the Adder program. At the same time, opening up of numerous financial schemes led to proper credit-risk management to the investors.

Although considered an important program for decentralized energy development by motivating the small investors, the adder rate pass through the customers equally causing electricity tariffs go relatively higher. In an attempt to adjust the right FiT, Thai government initially stopped application for solar under adder program and later for all other renewable sources, which created a lack of trust for the investors.

The Adder program has resulted in increased renewable energy project development, from just 100 projects at the end of 2006 with a total installed capacity of 4,160 MW and a total proposed sale capacity of 2,344 MW to 316 projects, with a total installed capacity of 5,664 MW and a total proposed sale capacity of 3,120 MW as at the end of 2011.

3.3.2 Project specific case study: Solar Home System: an approach for electrification of rural household

1. Background Information

Solar home system (SHS) in Thailand is another program in context of decentralized energy which helped provide electricity to the rural households. SHS is a stand-alone system based on Solar PV. Following the main target of Provincial Electricity Authority (PEA) to expand electricity access throughout the country, especially to restricted and remote areas where grid extension was not possible, solar home system (SHS) was considered a strong solution to address such deprivation of those rural villages. This programme was started in 2004 to electrify the remaining 1% villages, where grid extension was not possible.

In 1972, only 10% living outside Bangkok had electricity access whereas the statistics thirty years later is 99%. . Thus, Thailand's rural grid-based electrification programme is considered a success story, which began in 1974, increased the number of electrified villages from 20% in 1975 to 99 % by 2004.

The government's accelerated-rural-electrification-programme between 1975 and 1996 helped expand the grid overwhelmingly, thereby resulting in a rapid growth in electricity access. As a consequence, significant number of villages were electrified viz. 44 % by 1981 and by 1986, 75 % of the villages received electricity. The rural electrified villages reached 98 % by the end of the programme in 1996. High cost prohibited the electrification programme to be implemented for the leftover. Unless the area is provided with a reasonable consumer density, a long grid extension is not cost-effective at all. Grid connection seems to be out of question in rural villages where the consumer density is very low. Thus, the Provincial Electricity Authority (PEA), the country's dedicated rural electricity utility, started focusing on the use of stand-alone electricity generation, particularly solar PV systems for non-electrified villages as this system is considered as providing an acceptable alternative despite their relatively high initial cost. SHS, started in 2004, was implemented over 2 years of time spanning all the rural households deprived of grid electricity. The total number of such households identified was 290,716. This was a programme initiated by Thai government which was implemented at provincial scale. PEA was made responsible for the implementation of the programme. In addition to providing electricity, this programme also targeted to add about 34 MW (290,716 x 120 Watt) of electricity in the decentralized energy portfolio.

2. Rationale

Since 1997, there had been a shift from electrifying villages to households and more than 550,000 households were provided electricity access in two phases. Only less than 1 % of the households lacked electricity by 2004 and most of these households are located in national parks, forests, islands, etc. Reaching many of the villages in Thailand are difficult by transport, especially those in mountainous region. This makes grid connection impossible on both economic grounds and terrain in number of villages. Thus, as an extension of all the earlier rural electrification programme, off-grid solar home system (SHS) became the need of time to make electricity access possible in for 1 % of the total villages, as a part of rural electrification through decentralized energy. The percentage of villages deprived of electricity might look meagre, but the government's effort to make electricity ubiquitous within the country is laudable.

Thailand's initiative for electricity access to rural villages by using a cleaner renewable energy form makes this approach reasonable to our study of "Decentralized Energy Interventions and its success in Thailand", under a project- specific theme (Off-grid).

3. Methodology

The required information for this case study module are based on secondary sources, basically the published and unpublished paper. Information was drawn from various websites which illustrated the process of development of SHS. A report on recent survey has been considered in this case study module to highlight some criticism on follow up after installation.

4. Key Characteristics

An investment budget of 7, 631 Thai million Baht (~USD 218 Million, 1 USD= 35 THB in 2005) was announced for the non- electrified rural households. The Government then, made a two year plan to electrify 290,716 households though the solar home system and complete by 2005: 153,000 within the year 2004 and the rest by the next year. Each unit of solar home system contained one photovoltaic (PV) module for 120 Watt, one set of 125 AH battery, one set of inverter and 2 sets of 10 watt fluorescent lamps. Each unit is capable of providing electricity for television for up to 4 hours.

PEA identified such rural households in different provinces and the four regions in Thailand. The work was carried out by PEA's administration offices. During the time of implementation, each region had 3 electric administration offices, thus 12 such offices altogether. The service was rendered by 73 provincial electric works, 729 Amphoe Electric works and 139 customer service units. The finance was channelized through Ministry of Interior.

Not only it provided electricity access to the rural community but also led to socio-economic development of the country. This project led by the government resulted in the establishment of about five solar module manufacturers in Thailand. This project also created interest and better understanding about solar energy and its benefits to both government sector and private sector.

5. Technology and Energy Services

The schematic diagram of solar home system is shown in the Figure (3.7) below. Solar PC array was installed in a separate pole as the roof of the houses in the rural villages are not strong enough to stand this purpose.

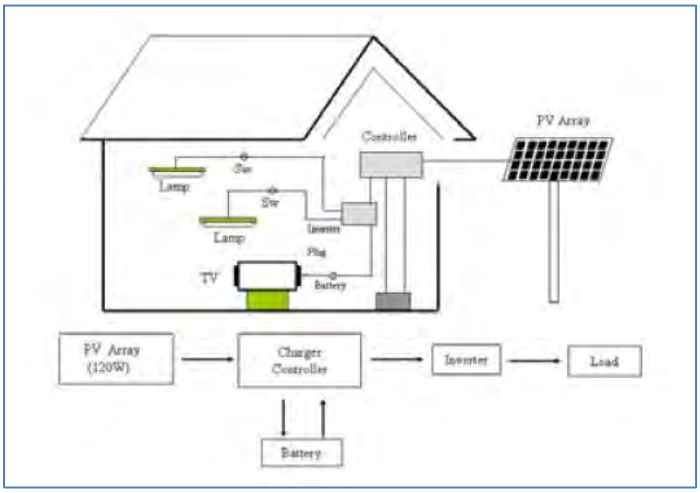

Figure 3.7 : Solar home system (SHS) installed in Thailand

A direct current (DC) is produced from the solar panels once the radiant energy of the sun reaches the panel. An array is formed by connecting these panels either in series or in parallel to produce a higher or desired voltage across the circuit. This makes the electrical voltage usable for specific applications. Batteries, which serve as storage devices, are coupled with the PV systems which mainly store energy produced during the day and thus makes it available whenever required, even during nighttime or overcast weather. At times, batteries also serve to power the array in order to stabilize voltage, as the intensity of solar radiation varies throughout the day and so does the output.

Two options for mounting the PV modules could have been used viz. fixed mounting or mounting on a tracker. The latter option would result in better output but the associated cost and maintenance are high. Therefore, considering the budgetary limitations and the villager’s lack of familiarity with the technology, fixed mounting was used. Figure (3.8) below shows the solar panel installed in an open land in front of households.

Figure 3.8: Thailand's SHS- fixed mounted PV modules

6. Delivery mechanism

The Thai-government started electrification program for rural areas that are inaccessible to the grid (1%) through SHS programme. PEA was made responsible for contracting with various private companies for the installation of SHS across Thailand. The energy services provided by the SHS was aimed at rural households, deprived of electricity and provided basic electricity requirement such as lighting two 10-watt light bulbs and a television/radio for a few hours in a day. Approximately half of these systems are located in north-western Thailand. Many of these are in nationally protected forests and along the Thailand-Burma border, as shown below.

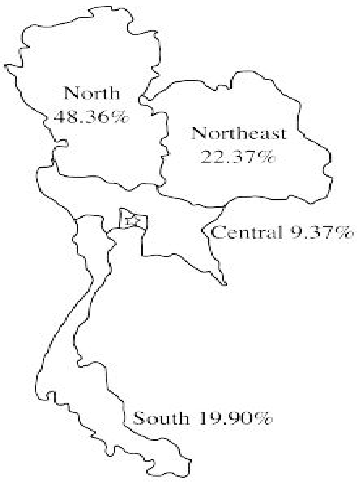

Figure 3.9: Percentage of SHS by region

Multiple companies including Solartron and Acumen, manufactured the components of the SHS and installed the systems, with Solartron distributing the majority. Solartron built approximately three-fourths of the PV panels, while the remaining fourth were distributed by Bangkok Solar Public Company Limited. More recently, ownership of the SHS has been transferred to the local sub-district governments, or tambons, who oversee multiple villages.

For this particular decentralized energy programme in Thailand, the institutional model which was employed, is the donation model. In this model, the initial investment of the systems and their installation are borne by government or charitable organization however, the users take care for their ongoing maintenance. This model has been used with varying success around the world with the second largest program, behind Thailand, in Mexico.

The overall structure for SHS in Thailand is very simple. The Ministry of Interior (MOI) financed the scheme of Solar Home System and PEA undertook the responsibility of completing the rural electrification program. The rural villages were identified and with the manufacturing and installer companies, Solar Home Systems were installed in the households of rural villages which were inaccessible to grid.

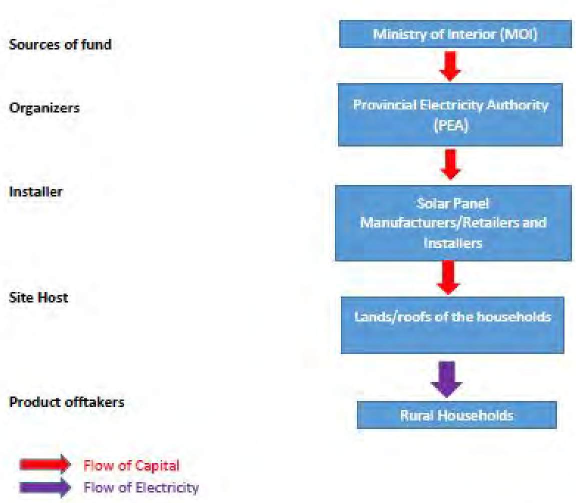

Figure 3.10: Different Players in SHS

The above Figure (Figure 3.10) clearly depicts the different players and stakeholders involved in the solar home system, beginning from the project investment to the end use.

This project facilitates rural households for basic lighting, radio and televisions. The ownership is held by the local sub-government, or tambons which oversee multiple villages. Installer companies like Solartron (which installed majority of the SHS) were paid by PEA against the complete system components and installation. The Provincial Electricity Authority (PEA) is a government enterprise and is responsible for the provision and distribution of electricity to all classifications of customers in the service area covering 73 out of 76 provinces all over the country, except Bangkok, Nonthaburi and Samutprakan. The project investment was channelized through Ministry of Interior (MOI). Additionally, an effective chain of communication against failure was also set up, which is shown below (Source: PEA SHS Manual).

A communication channel had been prepared by PEA for corrective maintenance of SHS. For such, each villages have a tambon representative and in the event of SHS failure, the villagers were to contact the representative, who should contact the local tambon office thereafter. The installation company should then send out technicians to the site of the failure. In addition, records would be passed along to the different levels of PEA and eventually to the main program facility in Bangkok.

7. Driving Factors

Thailand has a tropical climate with an ample humidity. There are three distinct seasons: the hot season usually has temperature ranging from 30-40 °C, the rainy season brings about billowing clouds and cool showers, and during the cool season, the temperature drops to about 8°C and sometimes can be lower than 10°C in certain areas such as the mountains in the North and the northeast. From the "SOLAR MAP of THAILAND" the yearly average solar energy per day is about 5 kWHr/m2, therefore the amount of solar energy falling on the area of around half a million square kilometers each day would be quite meaningful for further consideration.

Moreover, there are few dominant points which helped drive this programme further. These are:

- Cheaper method for electricity access than grid connected system
- Sufficient solar radiation
- Clean and green energy-form
- Elevate the quality of life of rural population
- Meeting the Renewable Energy Targets of the country

In addition, the villages in rural Thailand consists of small number of households, consisting 5 to 10 houses, each having 5 to 10 members. Such villages are located too away from the grid. Therefore, extension of grid in such villages is not economical. This reflected a strong driving factor to implement a clean decentralized energy in those villages. With optimum solar radiation, Solar Home System stood as a strong alternative to address the rural electrification need of the country.

However, SHS system also have been criticised under certain grounds. While the SHS programs have the advantages of economies of scale and equal distribution of the systems, users hardly feel ownership for such and thus, the program lacks user's involvement. In addition, sufficient awareness program for the system education should be conducted so as the sustainability, or functionality over a long period of time. Another criticism of this programme is about the government's inability to plan for repair and maintenance. Many of the SHS are found to be not working. A Non-governmental organization, Border Green Energy Team (BGET) is working towards such repair and conducting training for locals to make them acquainted with the system.

4 Situation analysis of China's decentralised energy sector

4.1 Section I: Background research

4.1.1 Country profile

China, officially known as the People's Republic of China (PRC), is the world's most populous country, with a population of over 1.35 billion. China has had the world's largest and most complex economy for the past 2,000 years, during which it saw cycles of prosperity and decline. Moreover, ever since the introduction of economic reforms in 1978, China has become one of the world's fastest-growing major economies. As of 2013, China is the world's second-largest economy both by nominal total GDP and by purchasing power parity (PPP); it is also the world's largest exporter and importer of goods. As a result of two decades of rapid economic growth following the initiation of economic reform in 1978, China has been experiencing rapid urbanization created by one of history's largest flows of rural–urban migration in the world. Indeed, by the end of 2013, 53.7% of the total population had moved to urban areas, a rate that raised by 26% since 1990.Additionally, according to official forecast the urbanization rate will reach up to 60% in 2020.This rapid economic development during recent years has resulted in relatively high income growth rates for urban and rural households. Furthermore, the composition of income has also changed during this period.

China has jurisdiction over 23 provinces, 5 autonomous regions, 4 direct-controlled municipalities, and 2 mostly self-governing special administrative regions. The people's congress system is China's fundamental political system. National People's Congress (NPC) and local people's congresses at all levels are organs representing the people in exercising state power. The people's congresses have four main functions and powers: legislation, supervision, appointment and removal of officials, and making decisions on major issues. These functions are a major reflection of the way the Chinese people exercise their power as masters of the state through the people's congress system. Multi-party cooperation and political consultation under the leadership of the CPC constitute the basic party system in China. Under the dual leadership system, each local Bureau or office is under the coequal authority of the local leader and the leader of the corresponding office, bureau or ministry at the next higher level.

Energy profile of the country reveals some interesting dimensions. In 2010, China was the world's largest energy consumer with a total final energy consumption (TFEC) of 57 extra joules (EJ) per year (or 1,950 million tonnes of coal equivalent), which is equivalent to 18% of the global TFEC (IEA, 2012a). In addition, according to the New Policies Scenario in the International Energy Agency's World Energy Outlook (WEO) 2012 (IEA, 2012a), China's TFEC is projected to grow by 60% between the period of time from 2010 and 2030.Furthermore, according to IEA and China National Renewable Energy Centre (CNREC) estimates, during this same time period, , China's share of modern renewable in the TFEC will grow from just 7% in 2010 to 16% in 2030 (excluding traditional uses of biomass).

As the largest energy consumer in the world, China plays a pivotal role in the global transition to a sustainable energy future in an increasingly 'carbon-constrained' world. Important to realize, the country is already a global leader in renewable energy, with massive potential to harness a diverse range of renewable sources and technologies, both for power generation and end-use sectors. Under current policies and investment patterns, the share of renewable in China's energy mix is projected to reach 17% by 2030 as compared to the 13% in 2010.

4.1.2 Energy resources and technologies

China has a long history of using various renewable energy resources, including biomass, solar, geothermal, ocean and wind energy. Renewable energy technologies produce marketable energy by converting natural phenomena/resources into a useful energy forms. These resources represent a massive energy potential, which greatly exceeds that of fossil fuel resources. Evidently, the usage of renewable energy resources is a promising prospect for the future as an alternative to conventional energy. From the government work report of 2015, fossil energy consumption still takes 64.4% in total energy consumption with 12.0% for non-fossil energy. It is predicated that the consumption of fossil energy consumption will be reduced to 62.0% and non-fossil energy increased to 15%.

Type of Power Generarion	Installed Capacity (GW)
Hydro Power	8291
Thermal Power	42216
Nuclear Power	1115
Wind Power	1383
Solar Power	84
Other	2.8
Total	53091.8

Table 4.1 : Installed capacity of different power generation in China in 2013

With the rapid growth of economic and social development, the requirement for power generation and consumption has grown quickly. For the power generation situation in China, thermal power still takes the biggest role. The percentage of renewable energy generation and decentralized power supply is still very small. As a matter of fact, in 2012 China had 34.3 GWe of decentralized energy capacity, of which 26.7 GWe was accounted for. Wind power is one of main types of decentralized energy in China; moreover at the end of 2013, total installed capacity had reached 9.14 GWe; making China the world's leading consumer of wind energy (GWEC, 2014a). Equally important, the solar PV projects in China are increasing with the greater installed generation capacity based on solar PV.

4.1.3 Energy services and requirements

China is the world's most populous country and has a rapidly growing economy, which has driven the country's high overall energy demand and the quest for securing energy resources. China is the world's second largest oil consumer behind the United States, and the largest global energy consumer, according to the IEA. The country was a net oil exporter until the early 1990s and became the world's second largest net importer of oil in 2009. China's oil consumption growth accounted for half of the world's oil consumption growth in 2011. Natural gas usage in China has also increased rapidly in recent years, and China has looked to raise natural gas imports via pipeline and liquefied natural gas (LNG). China is also the world's largest top coal producer and consumer and accounted for about half of the global coal consumption, an important factor in world energy- related $C0_2$ emissions.

Coal supplied the vast majority (70 percent) of China's total energy consumption of 90 quadrillion British thermal units (Btu) in 2009. Oil is the second-largest source, accounting for 19 percent of the country's total energy consumption. While China has made an effort to diversify its energy supplies, hydroelectric sources (6 percent), natural gas (4 percent), nuclear power (1 percent), and other renewables (0.3 percent) account for relatively small shares of China's energy consumption mix. The Chinese government set a target to raise non-fossil fuel energy consumption to 11.4 percent of the energy mix by 2015 as part of its new 12th Five Year Plan. EIA projects coal's share of the total energy mix to fall to 59 percent by 2035 due to anticipated higher energy efficiencies and China's goal to reduce its carbon intensity (carbon emissions per unit of GDP). However, absolute coal consumption is expected to double over this period, reflecting the large growth in total energy consumption.

From1997 to 2002, the energy intensity of exports and government expenditure recorded rapid declines, while the energy intensity of household consumption decreased more slowly than other final demands. Furthermore, after 2002, the household and government expenditure’s share of embodied energy declined roughly around 9% on an annual basis; whereas, the share of exports grew by roughly 9% on an annual basis. Despite the 17% average growth annually from 2002 to 2004, investment’s share of embodied energy remained roughly constant between 2002 and 2004.

Consumption poses a challenge for Chinese policymakers over the longer term, as China enters a period of more energy intensive consumption, and the timing of energy demand saturation seen in many OECD countries remains uncertain for China. Per capita energy consumption in China is still dramatically lower than in other OECD countries, but total residential energy consumption is already quite high. Certainly, the domestic and global environmental implications of sustained growth in consumption, more so than other sources of final demand, call for a dramatic scaling up of alternative energy technologies including decentralised energy systems in China.

4.1.4 State of decentralised energy systems

Decentralized energy systems derived from local and external sources have received wide attention in recent years. Decentralized energy systems generally cover a wide range of technologies and energy sources. These include: (among others) renewable energy technologies (e.g. photovoltaic arrays, wind turbines, micro-turbines, reciprocating engines, combustion turbines, and steam turbines); energy storage devices (e.g., batteries and flywheels); and combined heat and power (CHP) systems. These systems could be either on-site, self- or captive, or embedded generation facilities; moreover, they are suitable for the efficient production of energy/electricity near the point of use, regardless of size or technology. Decentralized energy systems typically use renewable energy sources, including, but not limited to, small hydro, biomass, biogas, solar power, wind power, geothermal power; not to mention these systems play an increasingly important role for the electric power distribution system. A grid-connected device for electricity storage can also be classified as a Decentralized energy systems system, and is often called a distributed energy storage system (DESS). By means of an interface, DER systems can be managed and coordinated within a smart grid. Distributed generation and storage enables collection of energy from many sources and may lower environmental impacts and improve security of supply.

In contrast to large centralized facilities, decentralized energy systems offer key benefits including: opportunities to utilize renewable energy technologies, minimizing transmission losses, reducing pollution, strengthening energy security, reducing electricity price fluctuations, and lowering energy costs. In fact, substantial benefits can be gained from an operational perspective, since transmission costs and losses can be dramatically reduced.

In China, decentralized energy system mentioned as "Distributed Generation" more often in related document and has several similar definitions. Its definition from "Regulation on Distributed Power Generation" issued by National Energy Administration is "Distributed generation is located near users, installed a smaller power mainly by the user for personal use and on-site generation facilities using renewable energy, resources or power output of energy cascading utilization system". National Grid Company gives the definition on distributed PV generation like "distributed PV is located near users and used locally, and electricity generated below 10,000 volts can be connected to the grid. The capacity of the single or network distributed PV station or project is designed up to 6MW.

Decentralised energy is largely promoted through various government initiatives such as laws and regulations, economic encouragement, technical research and development, industrialized support and government model projects, etc. Several decentralised technologies have been used in the country as discussed briefly below;

Solar energy and decentralized PV

Currently, China's solar energy is mainly intended for urban and rural domestic energy use and the power supply for remote areas. Solar water heater, passive sunshine house, solar furnace and photovoltaic cell all experience various levels of development. By the end of 2005, the installed capacity of photovoltaic power generation had reached 70,000 kW; the power generation had exceeded 100,000kW, the installed area of solar water heater had exceeded 70 milllion m2. According to the regulated goal, to the year of 2010 and 2020, the photovoltaic power generation could reach 300,000 kW and 1.8 million KW, respectively; the solar water heater installed area could reach 150 million m^2 and 300 millionm^2, respectively (Peidong and Yanli et al., 2009).

Wind Energy

China began to employ wind energy at an early stage. It is in 1958 that some provinces and cities began to research and manufacture 5 kW small wind energy water pumping generators. As early as 1978, 100 W and 250 W wind energy machineries were introduced to pump water and to produce power. By 2005, a total of 61 wind power plants have been completed, with a total installed capacity of 1.266×10^6kW . According to programs, in the years of 2010 and 2020, the wind power installed capacity of State Grid would reach 5.0×10^6 kW and 3.0×10^7 kW, respectively.

Biomass energy

The employable biomass energy in China mainly include crop stalks, firewood, foul wastes, domestic garbage, industrial organic waste residue and waste water, etc. It is estimated that the total exploitable biomass energy in China is around 700 million tce. By 2005, 1.716×10^7 marsh gas pools have been constructed throughout the country, more than 3090 large-and middle-sized marsh gas projects, with an annual production of $8.5 \times 10^9 m^3$, the biomass energy power generation was 2.0×10^6 kW (Peidong and Yanli et al., 2009).

Small hydropower

Small hydropower in China refers to the small hydropower generations with installed capacity of less than 5.0×10^3 kW (including 5.0×10^3 kW). As a counter check on the state water resources shows, the exploitable part of China's rural small hydropower resources techniques is 1.28×10^8 kW and the power generation is 4.5×10^{11} (kW h)/a. Up to 2004, the installed capacity in the exploited small hydropower plants had reached 3.45×10^7 kW, accounting for 27% of the total exploitable resources. The installed capacity of the exploited small hydropower plants accounts for 35% of the total capacity in China (Peidong and Yanli et al., 2009).

Geothermal energy

Geothermal energy refers to the heat contained in the rocks and geothermal fluid more than 5000 m under earth crust with the temperature above 15℃. China abounds in geothermal resources. More than 3200 geothermal spots have been found, with an annual naturally relieved heat of 1.04×10^{17} kJ, i.e. 35.6×10^8 tce, among which 80% are geothermal hot land below 100 8C. This determines that China's geothermal resources are mainly directly used.

4.1.5 Variants of decentralised energy systems

There are various types of distributed energy resources and in China, large-scale high-efficient coal-fired heat and power cogeneration is one form of such systems. In the process of the utilization, the heat energy and the electricity energy are two basic ways of utilizing end-use energy. A combined use of electricity and heat energy can improve the utilization of energy, save resources and protect environment. At present, distributed energy resources mainly use the natural gas, but renewable energy power generations like wind power generation, solar photovoltaic power generation and biomass power generation are also applied. Distributed energy systems are environmentally friendly and help to conserve resources and reduce release. However, as distributed energy resources lack market competitiveness, relevant supporting and preferential policies are needed to protect the development of these resources. In 2004, the NDRC of PRC released the *Report on Relevant Issues on Distributed Energy Resources Systems*. In this report, the concept, feature, and development focus of DER are clearly explained for the first time.

(1)Business model

Faced with the prospective and environmental protection significance of the development of distributed energy, many of China's enterprises have participated in the development of distributed energy, the first to carry out the construction of many distributed energy projects. According to statistics, China has built to run 59 distributed energy projects, whose installed scale is 1.76 million kilowatts, mainly in large cities like Beijing, Shanghai, Guangzhou, etc. At present, China's distributed energy economy has not yet formed industry scale, and many technical problems remain to be solved. For its high cost, it mainly relies on the government support at this stage. In the power problems, it is difficult for distributed energy to generate energy and connect the Internet, and its price is low compared to environment costs, lack of competition with general power. Institutionally, China's power grid is powerfully monopolized by large-scale power grid companies, but monopoly groups are not keen on the development of distributed energy, thus impeding the development of distributed energy system.

For distributed energy, the main energy comes from wind, solar, natural gas other clean energy. Among them, the solar photovoltaic market develops strongly, and the global photovoltaic markets are upgrading significantly, the new increase rate of global PV industry reach up to 80%. Since 2013, China has been the world's largest PV market, and continues to keep leading status.

Natural gas, as clean energy having been developed for a long time, plays a very important role in the development of distributed energy. Natural gas distributed energy project mainly include the independent operation mode built and operated by the investor and commission operation mode.

Business model for PV power

The structure of investment on decentralized PV power system is complex and there is still not very clear definition. However, there are mainly 3 types business model for now for the operation on PV power investment.

Business Model	key features	Advantage	Disadvantage	trigger factors
Total grid connected PV power station model	The investor is responsible for the PV power station's construction, maintenance and operation. All the electricity generated by the power station will be sell and connected to the grid. And the investor got the subsidy by the generation capacity following the policy and relevant regulation.	This model has a low impact on safety of grid system operation and also easy for calculation of the subsidy by generation capacity.	Targeted the roof solar project with above a certain installed capacity usually invested by the state owned or public service sectors	Special fund from the central government finance; Country duty and pressure on carbon emission reduction by setting the demonstration project
Energy Performance Contracting (EPC)	The third party invest the project and is responsible for the funding, construction of the PV project. The electricity will satisfy power need of the consumer close by the project and the left over can be sold and transported to grid. The investor	The power generated satisfy the close by consumer first to improve the energy efficiency	The motivation of investment is complex. There are 3 types of usage pattern: total for local investor self-use, total for	Subsidy caused economic benefit

	will get the subsidy based on the capacity generated.		other consumer and the mixing pattern. Difficulty to deal with the benefit appeals from the investor, power generator and traditional power supplier	
Self-own PV power model	The consumer invests the PV project by themselves and the electricity generated for themselves use first and if any leftover power will be sold to grid.	Providing power for the people in rural area	A certain amount of investment capacity by the consumer and requirement for relatively high energy demand	Subsidy policy ; Willing of energy saving ;

Table 4.2: Business model for PV power in China

Exchange models based on technology

Household solar system is power generation by small photovoltaic power generation system of their own household during the daytime, and storage battery power inverter for discharge and supply load during evening. The PV module, controller, inverter, battery. Photovoltaic components, solar panel is the core part of the solar power system, the highest value is also part of the solar power system. It plays a role to convert solar energy into electricity, to store into batteries, or to promote the work load. The quality of solar panels and the cost of the entire system will directly determine the quality and cost. The solar controller is composed of a dedicated processor CPU, electronic components, display, switching power tube. The direct output of PV modules is generally DC, and DC needs to be generated by solar power generation system, which can be converted into electrical energy requiring the inverter. The inverter is a kind of direct current (DC), which alternate the current (AC) device. High quality AC can drive any kinds of load; however the technical requirements cost a lot. Sine wave inverter can meet most of our power demand, it becomes the mainly product in the market. In addition to solar photovoltaic cells, solar water heater is the main form of the Chinese solar dispersion and utilization, saving resources, optimize energy utilization rate.

Innovation of financial instrument has also stimulated development and progress of solar-power project. Through financing, merger and financial derivatives, capital integration and industry development has grown fast.

Main Trigger Factors

The development of distributed energy is under multidimensional influence coming from technology, policy, system and market. The technology factor considers about energy design, operation of distribution gird, grid safety, stable and reliable performance and so on. Recent technology concerning grid performance has become the main limiting factor. Because synchronizing distribution energy into national grid will add the risk of system breaking down. Meanwhile, existing grid program design, grid safety system, possible fluctuation and auxiliary devices have all become its factors.

Policy and system factors include policy, policy formulating, policy implementation and institutional structure which directly or indirectly affecting distributed energy project. Market factor consists of economic properties and market structure of distributed energy. Economic properties refer to design and operation costing, financing element and so on, while market structure refers to proportion of participants and pricing and transaction system. These elements all influence distributed energy project and makes it rise and fall. In China, national policy has undisputedly become the main promoting factor concerning its high cost and defective trading system in distributed energy. The guide and encouragement of national policy will not only stimulate some entrepreneurs and groups taking the first leap of it but also accelerate the popularization of distributed energy being used nationwide.

Central governmental financial support plays an important role on launching special development fund for decentralized energy system going with corresponding finance and tax supporting polices. The central financial supports include investing the decentralized energy facility utilizing the renewable energy like wind, solar to provide electricity generation for the people in Northwest China rural area, where has no access with centralized power supply. In addition, this can provide the financial subsidy for the decentralized energy system from the country level.

4.2 Section II: Assessment of country specific policy, regulatory and other incentives

The Chinese government is implementing multiple policies to promote decentralized energy system and especially to take the advantage of to use renewable energy, improve energy efficiency and reduce environment pollution emission. Decentralized energy system in China is completely new and recently being considered officially. Most importantly, these systems are based on the renewable energy resource and technology. Therefore, all the policies and regulations pronounced to promote renewable energy in the country are also meant to promote decentralised renewable energy systems.

From 2008 to January 2012, China held the top spot in clean energy investment. The Renewable Energy Law passed in 2005 explicitly states in its first chapter that the development and the usage of renewable energy is a prioritized area in energy development. The Twelfth Five-Year Plan, the current plan, also places great emphasis on green energy. Detailed incentive policies and programs include the Golden Sun program, which provides financial subsidies, technology support and market incentives to facilitate the development of the solar power industry; the Suggestions on Promoting Wind Electricity Industry in 2006, which offers preferential policies for wind power development; and many other policies. Besides promoting policies, China has enacted a number of policies to standardize renewable energy products, to prevent environmental damage, and to regulate the price of green energy. These policies include, but are not limited to Renewable Energy Law, the Safety Regulations of Hydropower Dams and the National Standard of Solar Water Heaters.

Related Policies, Laws and Regulatory Mechanisms of DER

After the dissolution of the Energy and Industry Department in 1993, which was established under combination of former departments for coal, oil, nuclear industry and water engineering in 1988, China has been running without a government agency effectively managing the country's energy. Related issues are supervised by multiple organizations such as the National Development and Reform Commission (NDRC), Ministry of Commerce, State electricity Regulatory Commission (SERC) and so forth. They have the branch department from country to province and city level with relevant responsibility. In 2008, the National Energy Administration was founded under the NDRC. In January 2010, the State Council decided to set up a National Energy Commission (NEC). The commission will be responsible for drafting a national energy development plan, reviewing energy security and major energy issues and coordinating domestic energy development and international cooperation.

Time (Year)	**Major Policy/Report/guideline**	**Key components related to the decentralised energy development**
2004	The Report on Distributed Energy System by NDRC.	Describes the **concepts, the characteristics**
2006	Ten Key Energy Conservation Projects in Eleventh FYP	"Regional co-generation of heat and power" was considered as one of the key components of the project
2006	National medium- to long-range program for scientific and technological development by NEA	Talks about policies for distributed energy
2007	Natural Gas Using Policy by NDRC	Defining the prior using types of natural gas, including distributed co-generation of heat and power and the users of cooling-heating-power co-generation.
2007	The Notification on printing and distributing The temporary management provisions of the co-generation of heat and power project and the comprehensive utilization of coal for power generation project by NDRC and Ministry of Construction	Talks about promotion of distributed co-generation of natural gas and coal gas to deal with the seasonal heat-supplying problems in medium and small towns.

2010	Technical regulations for the distributed generation's **accessing to the power grid**, by State Grid Corporation of China	Stipulating the general principle for newly built and expanded distributed generation to obey when it had accessed to the power grid.
2011	The guiding instructions on developing the distributed energy of natural gas, by four ministries and commissions including NDRC.	Constructing about 1000 distributed energy projects for natural gas and improving the financial aid and tax supporting policy during the period of 12th Five-Year Plan.
2011	The Notification on printing and distributing the working plan of controlling the greenhouse gas emission, by the State Council	Developing non-fossil energy, adjusting energy structure and promoting the expanding of the distributed energy system.
2012	Research report on the developing trend of new energy industry, by National Energy Administration	Explaining the developing focus of China's current distributed energy system
2012	The developing plan for town gas in china during 12th Five-Year Plan, by Ministry of Housing and Urban-Rural Construction	Gas consumption of the distributed energy projects would meet 12 billion cubic meters at the end of 12th Five-Year plan.
2012	Opinions on carrying out the government work report and the working division for key departments, by the State Council	Promoting energy saving and emission reduction, strengthening the energy using management and developing the smart power grid and distributed energy.
2012	Natural gas using policy by NDRC	Giving the priority to the distributed energy project for natural gas (synthetically efficiency for energy utilization can up to 70%, including synthetically using of renewable energy sources) and natural gas co-generation of heat and power project.
2012	The notification on the first batch of national natural gas distributed energy demonstrative projects, by National Energy Administration	For the first batch, we only have four national natural gas distributed energy demonstrative projects.
2013	The plan for energy development during **12th Five-Year**, by the State Council	Developing the distributed energy, coordinating the synthetically using of traditional energy, new energy and renewable energy. Achieving the harmonious development between distributed energy and centralized energy supply system.
2013	The temporary management provisions for distributed generation, by National Energy Administration	Encouraging professionalized energy company and individuals to make investment on the constructing and running the distributed generation projects and the **financial aids** would also be given to them.
2013	Opinions on service work of distributed generation and **grid connection,** by State Grid Corporation of China	In order to promote the developing of the distributed energy, State Grid Corporation of China promises to provide favorable conditions for grid connection, enhance the supporting grid facilities, optimize the procedures for grid connection and promote the service efficiency.
2013	The notification on achieving the goal of energy saving and emission reduction in 2013	Adjusting the energy structure, promoting the clean utilization of coal, expanding the using of clean energy like natural gas, coal gas and biomass briquette, developing the distributed energy.
2013	The notification on relevant issues of	Conditions developed regions can start the exploration of directly

	starting the directly dealing between electricity users and the power generation enterprises, by National Energy Administration.	dealing between users and power generation enterprises, and the industry parks and independent electricity allocation and sales enterprises can also take part in the dealing as the users.
2013	Action plan for **air pollution preventing**	Encouraging the development of natural gas distributed energy projects and limiting the development of natural gas chemical industry projects.
2013	The notification on several opinions for the development of the distributed generation	Fully open the client distributed generation market, encouraging the bringing of investment through the cooperative managing mode and the operating of distributed generation facilities. The grid should be improved and the allowance for the distributed generation should be guaranteed and the subsequent supervision should also be strengthened.
2013	Notification on price leverage to promote the healthy development of the photovoltaic industry by the NDRC.	Confirming that the subsidy for electricity generated from decentralized PV project is 042 RMB(0.068 USD approximately)/KWp
2014	The notification on relevant issues of standardizing the management for natural gas and power price, by the NDRC.	Encouraging the natural gas distributed energy to sign directly with the users and negotiate the electric quantity and price by themselves. The price for electricity produced by the new natural gas distributed generation should refer to the local electricity price.

Table 4.3 : Policies about distributed energy

China put forward the concept of distributed energy resources officially in 2004 and its importance has been greatly attached to since then. In 2011, China started to develop distributed energy resources in an all-round way. In October, 2011, the NDRC, the Ministry of Finance, the Ministry of Housing and Urban-Rural Development, and the National Energy Administration made a joint release of *Guiding Opinions on Developing Natural Gas Distributed Energy*, planning to build around 10 decentralised energy demonstration plots of typical features of different kinds. After that, China's decentralised energy projects stared to show up prominently. The *Policies on the Utilization of Natural Gas* released in 2012 included natural gas distributed energy in the list of preferential development in the utilization of natural gas, which furthered its development. In 2014, the NDRC published the *Notification on Regulating Grid Purchase Price of Natural Gas Generation*, improving transaction standards for prices of natural gas distributed energy. What's more, norms and basis for market transaction are also provided in this *Notification*. In 2006, China's 8 commission and ministries led by the NDRC published the *Implementation Opinions on Ten Major Energy Conservation Projects* *under the 11th FYP*, listing district heat and power cogeneration project as one of the ten key projects. It also completed standards and policies related to heat and power cogeneration powered by natural gas distributed energy. All of these have made natural gas distributed energy develop gradually all around China. Although related techniques are relatively mature, a mature market mechanism hasn't been established. Therefore, the scale of developing natural gas distributed energy requires further development. The detailed mapping of policies is presented in the Table 4.3.

Fiscal measures for distributed energy resource

However, in China, the distributed energy resource is still on the starting point. A series of policies on distributed energy resource have been issued to promote its development and get financial support. The financial support includes three parts: one is to offer privilege to the investment of distributed energy resource through financial subsidies based on the equipment capacity. At the point, lack of sophisticated technology in this field, it is important to identify the imported key equipment with tax free. As the technology of distributed energy resource develops, the government will cut down the favorable policy on import tax. In addition, financial organizations, such as banks give priority to offering loans on distributed energy resource program and supply interest relief. The government offers subsidies to the investment of accessible system of distributed energy resource. Secondly, the operation of distributed energy resource is subsidized. It is possible to offer a favorable price for the fuel in the system. For the suppliers of distributed energy resource, they enjoy the right of tax reduction or tax free. Thirdly, the government is committed to encouraging the research and promotion of home equipment. By doing this, the government gives priority to improving innovation incentives and security system, the research and development of relevant technology, technology transfer and industrial innovation system. Also, it is important to establish a specific fund on the research of distributed energy resource, introduce and adopt the advanced technology overseas, and finally pay much attention to innovation. Based on the Supporting Program of Distributed Energy System of Natural Gas and Fuel Gas Development issued in 2012, Shanghai became the first city to support the natural gas energy development. From 2013 to 2015, the government aims to provide RMB 1,000 per KW to equipment of distributed energy resource. Meanwhile, the gas suppliers should secure a limited supply for users and offer the favorable price. Major fiscal measures are captured in Table 4.4 below.

Policies	Content
Feed-in tariff	Bid pricing was adopted at the beginning in some area. After the official document issued by NDRC IN 2011, Feed-in tariff was introduced to set the price for the electricity generated by PV power when it was sell to the grid. This fund is from the renewable power plus foundation and targeted to promote the decentralized energy system by high price purchasing the electricity generated.
Subsidy on capacity	Solar Roof Programme(2009-2012) Funded from government financial allocation, subside the Building Intergrated Solar Power(BISP) project which has capacity larger than 50KWp.
	Golden Sun Programme(2009-2013) Subside the grid-connected and individual PV power project with a capacity above 300KWp; At the beginning, subside 50% of the total investment for the grid-connected project, and 70% of the total investment for the individual grid-off project in rural area; The amount and proportion of subsidy was adjusted with different regions and project capacity. Two types of subsidy ways includes certain amount and giving subsidy by proportion.
Tax incentives	Value-added tax concessions for PV projects; Custom duty concessions for PV related material or equipment; Enterprise income tax concessions for PV project; Other local governmental ta x concessions

Table 4.4: Main fiscal measures for decentralized energy

4.3 Section III: Case Study Module

4.3.1 Programme specific case study: Golden Sun Programme

1. Background information

"Golden Sun Project" is a policy initiated by China in 2009 to promote the implementation of the support of domestic PV industry technological progress and scale development and to foster strategic emerging industries, which will boost the development of China's PV power generation projects.

On July 21, 2009, the Ministry of Finance (MOF), the Ministry of Science and Technology (MOST) and the National Energy Administration (NEA) announced the launch of the Golden Sun Demonstration Project. The Project is to facilitate the growth and expand the scale of the photovoltaic (PV) power generation industry, and promote emerging strategic industries like new energy, energy conservation and environment protection industries with an aim to foster new sources for economic growth.

The three departments have jointly issued a Notice on Implementing the Golden Sun Project. Accordingly efforts will be made through fiscal subsidies, scientific and technological support, and market incentives to accelerate the industrialization of PV technology and enable large scale development of the PV industry. Pilot PV projects of no less than 500 MW will receive fiscal subsidies in the coming two to three years.

2. Support range

(A) Sufficient floor space available, a better grid access conditions, electrical load greater economic and technological development zones, hi-tech development zones, industrial parks, industrial parks contiguous focus of the user side of the photovoltaic power generation construction project, installed capacity capacity principle, less than 10MW

(B) The use of mining, commercial enterprises and public institutions of existing buildings and other conditions for building the user side of the photovoltaic power generation projects with an installed capacity of not less than 300kW.

(C) The use of smart grid and micro grid technology to build the user side of the PV project.

(D) Remote areas without electricity, the construction of independent photovoltaic power generation projects.

3. Support conditions

(A) The project must be self-occupied units in the power user, specialized energy service companies, distribution network (micro grid), one of the main investment management, and project the total capital investment of not less than 30%. Among them, the project implementation unit and project where the building owners for different subjects, must be signed long-term contract energy management agreement. Stand-alone photovoltaic power generation project owner, must have the ability to protect the long-running project.

(B) For demonstration projects focused on contiguous economic and technological development zones, hi-tech development zones, industrial parks, industrial parks, park management must combine the basic conditions for regional co-ordination of planning, set up a special management body and the appointment someone to coordinate the project, network access, operation and management aspects of the work, and to develop appropriate supporting policies.

(C) Demonstration projects must be cost-effective good design and reasonable size of the project, installation and construction, the basic matching network conditions, and easy transformation of the roof construction, renovation investment is low, the overall planning of the plant with the new priority support for projects .

(D) Project and network design meets specifications, the spontaneous generation in principle, for personal use.

(E) The use of key equipment items (including PV modules, inverters, batteries) unit independent from the implementation of the procurement and performance requirements of appendix 1.

(F) Independent photovoltaic power generation projects to the county (and above) for the overall implementation of the unit.

(G)Related to policy support project shall not repeat the declaration.

4. Subsidy standards

(A)The use of crystalline silicon components of the standard demonstration project grants to 9 yuan / watt, amorphous silicon thin-film modules for 8 yuan / watt.

(B)Independent photovoltaic power generation project subsidy standards to be determined.

Fourth, the project application and funding procedures issued

(A) Project implementation unit according to "Ministry of Finance, Ministry of Science and the Ministry of Housing and Urban Construction Bureau of the National Energy demonstration project on the strengthening of Golden Sun and solar photovoltaic building demonstration project construction management," (Finance Building [2010] 662) for the preparation of project requirements implementation of the program, according to the principle of territoriality reported provincial finance, technology, energy authorities.

(B) The provincial finance, technology, energy department in charge of the project application materials for rigorous assessment of the eligible project summary by category (see Appendix

(C) Ministry of Finance, Ministry of Science, the National Energy Bureau of the project review, public demonstration projects directory.

(D)Included in the directory contiguous focus demonstration projects and more than 2 MW and the user side of the photovoltaic power generation project, complete the review of the record and other preparatory work, the report submit applications for grant funding. Ministry of Finance approved grants in the budget by 70% of the issued and on June 30, 2012 liquidation; according to the specified deadline for completion of the liquidation of the project, the principle of reward money will be recovered, and no longer be arranged.

4.3.2 Project specific case study: A Decentralized Roof PV Project at Pudong, Shanghai

1. Background information

Under the policy promotion, pressure of carbon emission reduction and relatively mature development of PV technology, enterprises with suitable conditions using decentralized energy system are working together with the decentralized PV power generators to install this kind of new power producing system in their spare space. Depends on the installed capacity of the project, it can reduce the power usage in varying degrees from the national grid. If there are any left electricity generated from PV, it can be sold to national grid.

This project with 2.5MW designed electricity generation capacity, is installed on the roof of 3 different buildings of one company, which is located at Pudong District, Shanghai. It was designed to provide up to 30% power consumption of the whole company according to the current power requirement. The first phase of project with 1.7MW generation capacity has been installed in late 2015 and began to operating. The contract of this project was signed in May 2015 and the first phase 1.7MW capacity roof facility has been finished in December 2015.

This project was selected to be one case study with the reasons as follows: 1) this project is one typical demonstration decentralized solar power project in china, which is a profitable, replicable and sustainable commercial model can be referenced by other areas and countries. 2) Following the definition of decentralized energy system in China, this project is one typical project with a certain size (installed capacity and technical operation)can be a reference for other areas. 3) the relative mature experience on implementation of policy, subsidy incentives and cooperation between different stakeholders.

As the investment cost and efficiency of PV power generation, the profit-making ofthe generator still mostly rely on the subsidy from the government, and it will take different years to get the investment cost back depending on the size of the project. There are still some challenge and difficulties faced by the frontrunner of decentralized power generator, such as looking for the suitable consumer with good condition for project implementation, funding-raising for investing new projects, etc. However, experience of running this project on technical cooperation and operation mechanism can be shared with other area with similar condition for developing decentralized PV energy system.

2. Method

This case study analysis is based on the interview with the chairman of the PV solar company conducting out this project with related information and data provided including the "Implementation Report of Roofing 2.5MW distributed grid-connected PV power generation projects in Shanghai Hitachi Household Appliances Company (1st phase 1.7MW) "(Ruiwen Duan, 2015). More information and project pictures were collected from the field trip to the project site.

3. Actors, Roles and Outline of the project

This project is located in Pudong District, Shanghai and invested by Shanghai Shilite New Energy Technology Co., Ltd with a total amount of 20 Million RMB, and the engineering Procurement Construction(EPC) was implemented by Shanghai Safegreen Technology Co. Ltd. ,and the main technical installation was done during October to December 2015. Power generated from this project was consumed by Shanghai Hitachi. This project is connected with national grid and if there is any electricity left which is unused by the consumer, it can be sold to the national grid. This project is one medium size decentralized PV power system with a total capacity of 1.7 MW (installed now) and there are 0.8MW part is still under construction. The component used in this project is called Polycrystal 265Wp.

Figure 4.1: Project location at Shanghai Hitachi

In this project, there are four main actors including the local government, local national grid, the investor and power producer, and the consumer. This project is one typical case on decentralized PV power system in Shanghai, so the scale of the mechanism of this project is based on province scale (Shanghai is municipality directly under the Central Government as same level as the province) and also the technical part of PV power . As the local government department, Shanghai National Development and Reform Commission (NDRC) is very important to implement the related policy and incentives coming from the center government including Promotion and adjustment on the national policy, regulation related to decentralized energy system and guarantee its implementation in Shanghai, to approve the project starting, and to provide subsidies to the decentralized power generators. Shanghai Power Company is at the position to provide overall technical support between the decentralized energy system and national grid and to be the judge on the power generation capacity of the decentralized power generator. Its role and contribution includes setting the technical standard and to approve the grid connection from the decentralized energy system, and it the third party for judging the electricity generation capacity from the decentralized energy system. Shanghai Shilite New Energy Technology Co., Ltd. Is the investor of this project providing the total loan for this project and Shanghai Safegreen Technology Co.Ltd is the main implementer of this project and is responsible for Project design, installment and maintain for the system and it will get the subsidy from the government. Shanghai HITACHI Company is the consumer of this project providing suitable roof placing the project,consumption of the electricity generated from the decentralized energy system and coordinating the cooperation for the operation of the project. And this mechanism organization can be seen from the Table (Table 4.5) below.

Related Entity	Basic Information	Role
Local Government : • Shanghai National Development and Reform Commission(NDRC) and its branch at related District	Sector: Public, Environmental, Financial, Ownership: Public	• Promotion and adjustment on the national policy, regulation related to decentralized energy system and guarantee its implementation in Shanghai. • To approve the project starting • To provide subsidies to the decentralized power generators
Local-National Grid • Shanghai Power Company	Sector: National Grid, Professional standard Ownership: Stated own	• Setting the technical standard and to approve the grid connection from the decentralized energy system • The third party for judging the electricity generation capacity from the decentralized energy system
Local decentralized PV energy company and investor Shanghai Shilite New Energy Technology Co., Ltd. Shanghai Safegreen Technology Co.Ltd	Sector: decentralized energy generator Ownership: Private	• Project design, installment and maintain for the system • Subsides gainer • Engineering Procurement Construction • Investor
Customer Shanghai HITACHI Company	Sector: User Ownership: Joint venture(State-foreign)	• Consumption of the electricity generated from the decentralized energy system • To provide suitable roof placing the project • Cooperation for the operation of the project

Table 4.5: Project actors and their roles

Figure 4.2: Project construction finished

4. Outline for the project process

To make this project happen, there are 8 main steps including:

Figure 4.3: Project process outline

5. Technical composition

The whole decentralized PV power system is composed with five sub-systems, including the photo-translating system, inverter system, alternating-current system, monitoring system and other related supporting facilities. This project was designed that "power generated for local use and if any left access to grid". The project choose polysilicon (256Wp) solar battery as the main component as its mature technology and relatively stable efficiency. All the facilities and components are mostly produced in China and any other advanced technology and product will also be considered to adopt for use in order to improve the power generation efficiency and reduce the cost. The facilities of project, in particular the angle of slope of the solar panel, is set based on the site conditions of Shanghai solar radiation, roof condition of the consumer etc. This project is designed with unmanned on duty but with regular exterior inspection to maintain the project operation well. The computer monitoring system will do the general monitoring the work of invert, grid connection and measurement part. Meanwhile, video monitoring help to monitor the cleanness, damage and other related conditions of the solar panel. This information collected by the monitoring system will be sent to the operation and maintenance technician by internet for quick response.

6. Financial Arrangement

In this project, the total investment amount is 20 million RMB (approximately 3118 USD) and totally provided by the private investor. The design life of this project is 25 years and it will take 5 years at least to get the investment cost back based on the electricity price and subsidy now. At the first 20 years, the electricity generated by this project will be sold to the consumer with the price of 80% discount based on the price from National Grid, and the project will be donated to the consumer for free at the last 5 years. It should be noted that subsidy given to the decentralized energy generator is planned for 20 years according to the policy now.

This project proves that decentralized PV power system is economically viable based on the feasible price market modification and subsidy policy from central and local government. However, there is still difficulty to get the loan from bank to support the development of decentralized energy system investment.

After the project approved by the related department, the project (1st phase, 1.7 MW) construction was finished in December 2015, including roof condition check and smoothing, temporary facilities, holder and component assembling, check before the grid connection etc.

Electricity generation capacity calculation

Based on the test of operation, the 1.7 MW project will generate an amount of electricity of 1,920,000 KWh approximately. It only occupy 9.6% of the actual power consumption of the company at the working duration of decentralized PV system. It means that all the electricity generated from the project will be totally consumed and will not be need to transferred to the grid and make it possible to improve the efficiency more and get the best benefit. In addition, it will generate a total amount of electricity 428,480,000 kWh in 25 years after calculation based on the condition now, with an average generation capacity at 17,140,000 kWh per year.n accordance with the actual installed capacity, which is 1.7MW, the average annual power generation equivalent utilization hours can be calculated: 1,714,000kWh÷1.7MW =1008.2 hours.

From the calculation above, we can conclude that this project has generated approximately 42,848,000kWh in total, 1,925,000kWh in the first year and 1,714,000kWh per year during the past 25 years; the average annual power generation equivalent utilization hours is 1008.2 hours.

Economic Analysis

After the distributed roof PV project of 1.7MW being put into effect in Shanghai Hitachi Electrical Appliance Co., Ltd., this company would have the privilege to buy the electricity at a 20% discount in the following 29 years, and take over this power station in the next five years.

In Shanghai, the weighted power charge in the generating period of PV power station in 2015 is approximately 0.898 yuan/degree, not considering the price increase; the power charge of desulphurized coal-burning energy is 0.436 yuan/degree, not considering the price increase as well.

Although the measured percentage of power generated and consumed by oneself exceeds 95%, the factual percentage of power generated and consumed by oneself exceeds is 85%. During the first two years, the general contractor should be responsible for the cost of repair and maintenance for the power station; from the third year to the 20th year, the cost of repair and maintenance for the power station is taken from the 6%~10% of the benefit of the weighted power charge.

Specific forecasted benefit for every investment can be seen in the form below

1) The total one-time investment amount is 13.09 million RMB, the total generation capacity is 34,961,000 kWh approximately in the first 20 years, with an average generation capacity at 1,748,000 kWh per year;
2) According to the above-mentioned boundary conditions, in this project, the payback period of investment cost is less than six years, ignore inflation factor of grid electricity price and price rise of desulfurization of coal.
3) The net proceeds of investment during the twenty years of power station running add up to 22,973,000 RMB(afer-tax), with an average annual proceeds of 1,149,000 RMB/year(after-tax),
4) The investment annual net interest rates in the project is about 8.78%, the net proceeds per kWh is about 0.66RMB/kWh(afer-tax).
5) Above all, the project has stable and long-term proceed as investment in fixed assets, and has high investment value.

Key driving factors

Consumer with suitable condition

The decentralized PV power generators and their investors are mainly medium or small private enterprise. One reason is that state owned enterprise prefers to invest the large size of ground PV power station with their advantage to get the large area of space land and loans. The investment capacity, large power consumer and suitable roof condition are the 3 main points for the decentralized PV investor consideration.

The roof decentralized PV project relied on the roof and building conditions a lot. More flat and wide roof conditions means that they can get more area for laying the solar panels and spend less time, strength and expense on smoothing the roof to make it fundamental condition ready and safe for construction. Meanwhile, a large power consumer means that most or all of the power generated by the decentralized PV systems can be consumed totally to get the biggest benefit and no waste of energy.

Subsidies

Subsidies is one of the key driving factors promoting the decentralized PV generator in this case as it is related with the benefit very much. The electricity generated by the decentralized PV system in the project will be sold to the consumer with 80-85% of the price of Grid, which as around 0.146 USD/kWh. And they will get 0.068USD/kWh subside according to the generation capacity, which is measured by the national grid. The policy of subside on going will be effective for 20 years. It is suggested by the decentralized PV investor that a higher subside benefit will be better for them to get the investment cost back more quickly, even they can forgo the subside in the years after they get the investment cost back, as the power benefit from the consumer will support their company enough then.

Approval system and cooperation between departments

The approval system works well and efficiently in Shanghai case. Especially the local NRDC, and national gird company take their roles on administrative approval and grid technical connection, contribute a lot to the success implementation of this project. However, related professional standard and regulations need to be developed to ensure the market in order and safety of the project implementation.

5. Conclusion

A detailed assessment of the strategic policy and regulatory interventions, more specifically, the fiscal and financial instruments shaping the development of decentralised energy systems in the study countries presents some interesting insights. Though sectoral peculiarities differ significantly across study countries, it is interesting to note that all the three countries are experiencing some form of revolution in the energy sector with specific thrust on transiting to a clean energy regime.

As far as the decentralised energy systems are concerned, it emerged from the assessment that there exists pluralistic interpretation of what constitutes 'decentralised energy systems' and it came out very succinctly from the analysis that the interpretation draws largely from the country contexts. The notion and nomenclature of 'what constitutes decentralised energy systems' differ depending on the country context. While decentralised systems in China and Thailand are more of grid connected in nature, it is off-grid in character in India. Of course, the decentralised energy interventions of grid connected types such as roof-top systems are an emerging phenomenon in India. In tune with the typologies of decentralised energy systems, the business models also differ across countries. In China and Thailand while the business models speak of designing various incentive structures for attracting private investors into the sector, in case of India, there has been a clear segmentation between publicly supported model versus private investor led models.

It emanates from the analysis that the larger economic and political settings of the countries govern the decentralised renewable energy sector to a significant extent. For instance, given the political setting of China, energy policies are largely decided at the federal level, whereas given the constitutional status of energy as a 'concurrent item', energy governance in India rests with both the federal government as well as provincial government. Moreover, the policy mapping exercise suggests that while China's energy policy making is heavily centralised (Burke et al., 2009), energy policy making in India is more cohesive and federally structured. On the other hand, energy policy formulation in Thailand appears to be somewhere between China and India and structured in a way where responsibility rests both on federal government as well as on provincial government.

It can be inferred from the mapping of incentive structures that there exist significant differences in structuring of incentive schemes across the study countries. Incentives in the form of subsidies, tax concessions such as tax holidays, relaxation of import tax and other taxes, a priority sector consideration for bank lending are widely used across all the study countries. However, there exist pronounced variations in the use of specific financial instruments in creating incentives for decentralised renewable energy systems. For instance, while preferential tariff is one of the key instruments used in China and Thailand, it is not employed in India for decentralised renewable energy systems/off-grid energy systems. Similarly, VGF as an innovative instrument is widely used in India and has not been considered an effective instrument in other two countries. Differences also can be observed in terms of variants of a particular incentive mechanism. For instance, subsidies as an incentive mechanism have been used differently in the study countries. While in Thailand and China, only investment/generation based subsidies are given, in India in addition to investment/generation based subsidies, some form of operational subsidies is also given.

In sum, the assessment also suggests that there have been efforts by countries to transit to smarter ways of subsidy disbursement. This is evident in each country's subsidy policies. In addition, there has been a clear emphasis to phase out from the subsidies.

On the tax front, it clearly emerges that there have been efforts to gradually move a low carbon regime. This is evident in consciously taken decision to put a price on carbon – at least in two countries i.e. in India and in Thailand.

Finally, it merits to highlight that Higher Education Institutions (HEIs) play critical role in accelerating the transformation towards sustainable development. It clearly emerged from the analysis that decentralised renewable energy systems have the potential to make the required transition in the energy sector to move to a sustainable development trajectory. More importantly, it clearly emanated from the study that higher educational institutes hold primacy in understanding the complexities of the sector and building the necessary skill sets to address such complexities. Given the global thrusts on renewable energy in general and decentralised renewable energy in particular, HEIs have crucial roles to play in creating the required pool of skilled man power through a variety of capacity building programmes and by offering innovative solutions through research.

6. References

Bahree, M. 2016. Who does most harm to global innovation? India, China and Thailand, Forbes, January 28, 2016.

DLA Piper. 2014. Renewable energy in the Asia-Pacific, DLA Piper.

GoI. 2006. Report of the Expert Committee 'Integrated Energy Policy. Planning Commission of India, Government of India.

Kaundinya, D. P., Balachandra, P., & Ravindranath, N. H. . 2009. Grid-connected versus stand- alone energy systems for decentralized power—A review of literature. Renewable and Sustainable Energy Reviews, 13(8), 2041-2050.

Hiremath, R.B., Kumar, B., Balachandra, P., Ravindranath, N.H., Raghunandan, B.N. 2009. Decentralised renewable energy: scope, relevance and applications in the Indian context. Energy for Sustainable Development 13 (1), 3-9.

IEA. 2015. India Energy Outlook. International Energy Agency. Paris, France.

McCrone, A., Moslener, U., Usher, E., d'Estais, F. & Grüning, C. 2016. Global trends in renewable energy investment 2016. Frankfurt School UNEP Collaborating Centre for Climate and Sustainable Energy Finance.

Ministry of Energy (Energy Policy and Planning Office). 2012.Summary of Thailand Power Development Plan 2012-2030 (PDP2010: REVISION 3). [Online]. Available: www.egat.co.th/en/images/about-egat/PDP2010-Rev3-Eng.pdf. [Accessed 28 11 2015].

Mishra, A., Sarangi, G.K., and Wadhera S. 2016. Off-grid Energy Development in India: An Approach towards Sustainability. Economic and Political Weekly, Vol. 51, Issue No. 22, 28 May, 2016.

Peidong, Z. and Y. Yanli, et al. 2009. Opportunities and challenges for renewable energy policy in China. Renewable and Sustainable Energy Reviews 13 (2): 439-449.

Shrestha, Ram M., Malla Sunil and Liyanage, Migara H. 2016. Climate policy and energy development in Thailand: an assessment. Regional Energy Resourced Information Center (RERIC), Asian Institute of Technology. ISBN: 978-974-8257-90-7.

Siddiqui, S., Upadhyay, S., 2011. Need for Integrated Policy and Institutional Framework for the Implementation of Jawaharlal Nehru National Solar Mission in Rural Areas. A Report of ELDF and Heinrich Boll Stiftung, India.

Siteur, J. 2012. Rapid deployment of industrial biogas in Thailand: Factors of Success. European Council for an Efficient Energy Economy, pp. 787-794.

Tongsopit, S. 2013. An assessment of Thailand's Feed-in tariff Program. Renewable Energy, vol. 60, pp. 439-445, 2013.

Tongsopit, S and Greacen, C. 2013. An assessment of Thailand’s feed-in tariff program, Renewable Energy, no. 60, pp. 439-445, 2013.

Tongsopit, S. 2015. Thailand's Feed-in Tariffs for Solar Power. [Online]. Available: https://www.google.co.th/url?sa=t&rct=j&q=&esrc=s&source=web&cd=8&cad=rja&uact=8&ved=0ahUKEwjLnor3uMXJAhUUW44KHRylDvIQFghHMAc&url=http%3A%2F%2Fwww.esi.nus.edu.sg%2Fdocs%2Fdefault-source%2Fevent%2Fsopitsuda_thailandssolarfit.pdf%3Fsfvrsn%3D2&usg=AFQjCNF5Pz. [Accessed 5 12 2015].

TERI.2009. Impact and adequacy assessment report. National Contract for Economic and Financing. Monitoring and Evaluation Frameworks and Policy and Institutional Issues. The Energy and Resources Institute (TERI), New Delhi.

World Bank. 2011. India: biomass for sustainable development. World Bank (South Asia Region).

World Bank. 2015. "World Bank," 2015. [Online]. Available: http://data.worldbank.org/country/thailand. [Accessed 11 11 2015]