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# Decentralized Energy Services Delivery in Developing Countries, Case Study: India

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ABSTRACT OF THE
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In developing countries, access to modern energy services is limited in spite of ambitious efforts of the governments and international development agencies like the World Bank. In this work, the importance of decentralized energy service delivery in developing countries has been investigated using the concepts of Service Engineering and institutional analysis of different delivery models is performed using the process mapping technique from the energy service provider's perspective. Decentralized energy service delivery has the theoretical potential to satisfy energy needs of the rural inhabitants. It supplements and strengthens the current centralized energy services delivery system in urban areas of developing countries. In addition, promotion of decentralized energy service delivery in developing countries will provide the necessary market-pull for renewable energy technologies. Decentralized energy service delivery by the market demonstrates the sustainability and scalability at an institutional level in developing countries. Small and medium scale enterprises play an important role in decentralized energy service delivery due to dispersed nature of potential end-users and needs to be promoted to improve access to modern energy services. Knowledge gap is the main challenge, as is evident from the walkthrough audit of the market delivery models, and this needs to be bridged in order to promote decentralized energy delivery through market approach.

Keywords: Energy access, Energy service delivery, Developing countries, Energy service provider, Service delivery process, Process mapping, Institutional analysis

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# Abbreviations

| | |
|---|---|
| BEE | Bureau of Energy Efficiency |
| CCS | Carbon Capture and Storage |
| DE | Decentralized Energy |
| ESP | Energy Servive Provider |
| GDP | Grass Domestic Product |
| GHG | Greenhouse Gases |
| HDI | Human Development Index |
| HPS | Husk Power Systems |
| ICT | Information and Communication Technology |
| IEA | International Energy Agency |
| LDC | Least Developed Country |
| LED | Light Emitting Diode |
| LPG | Liquid Petroleum Gas |
| MDGs | Millennium Development Goals |
| MFI | Micro Finance Institutions |
| NEDCAP | Non-conventional Energy Development Corporation of Andhra Pradesh Limited |
| NGO | Non Governmental Organization |
| NPBD | National Project on Biogas Development |
| NPIC | National Programme on Improved Chulhas |
| OSA | Opening Student Account |
| PDA | Public Development Agency |
| PV | Photo Voltaic |
| RET | Renewable Energy Technologies |
| SDA | State Designated Agency |
| $S^3IDF$ | Small Scale Sustainable Infrastructure Development Fund |
| SSA | Sub Saharan Africa |
| SHS | Solar PV Home System |
| SMEs | Small and Medium sized Enterprises |
| SSME | Service Science, Management, and Engineering |
| TET | Thrive Energy Technologies Private Ltd |
| UNDP | United Nations Development Program |
| SELCO | Selco Solar Pvt. Ltd |
| WEO | World Energy Outlook |
| WHO | World Health Organization |

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# 1 Introduction

## 1.1 Background

In many developing countries, access to modern energy services is limited in spite of ambitious policies and assistance from development institutions like the World Bank. This scenerio is mainly attributed to resource constraints (like finance, infrastructure and income) besides energy policies [[1], [2], [3]]. Nevertheless, provision of basic energy services is a top priority for governments and development institutions in developing countries.

The energy needs are often so small at the end-user level that locally abundant resources (renewable and human) are sufficient to satisfy the needs in a decentralized manner, i.e, decentralized energy services. This approach capitalizes on the modular nature of renewable energy sources and locally available resources and expertise. However, the major challenge is to create an environment that supports the utilization of the potential of decentralized energy services.

## 1.2 Motivation

Public development agencies and donor agencies have actively participated in decentralized energy services delivery, but achieved very little success in improving the energy service access. Decentralized energy services are bound by public service obligations in the initial stage due to the active participation of development agencies. Like any other public service, market participation is limited in the initial stages. However, the situations have been changing with the advent of new entrepreneurs in developing countries.

Existing research trends aimed at improving energy access in developing countries can be broadly classified into three types. The first approach is the development perspective, which focuses on the importance of access to energy services in developing countries and the impacts of current energy practices of the sections of societies that are suffering from modern energy poverty [4]. It recommends decentralized energy services delivery as an option to end energy poverty. [5]. The second approach is techno-economic analysis. This approach focuses on the evaluation of different technologies with economic insight for improving energy access in developing countries. In the case of decentralized energy services, this approach evaluates the importance of renewable energy technologies [[6], [7], [8]]. Economic policy reviews constitute the third approach. This approach emphasizes the importance of restructuring institutional structures to improve energy access in developing countries in general [[3], [9]] and does not give any specific importance to decentralized energy services delivery.

Decentralized energy service delivery is gaining momentum in developing countries by demonstrating commercial viability and environmental sustainability; however, it is in its early stage of evolution. Strengthening and promoting decentralized energy services call for institutional analysis besides the earlier research methods. This thesis is an attempt to do basic institutional analysis of different decentralized energy service delivery models in developing countries using the *process mapping technique*.

## 1.3 Aim and Scope

The aim of the thesis is to understand the importance of decentralized energy service delivery in developing countries. An institutional analysis of different delivery models using the process mapping technique from an energy service provider's perspective and service performance evaluation to understnad the end-user's perspective at the market level are also done as part of the thesis work.

The outcome of the thesis will provide a better understanding of decentralized energy services delivery in developing countries. It will assist energy service providers to strengthen and improve their operational performance using the outcomes of the institutional analysis. For other stakeholders, it will provide essential information for planning and promoting decentralized energy services in developing countries to achieve their strategic intentions in service delivery.

# 2 Process Mapping of Services

The process is the core concept of any system. A **process** is a set of distinct but complementary tasks that are organized in order to achieve a specific objective by employing dedicated resources [10]. Quality and productivity enhancement of the system requires basic understanding of the processes in a system. Process mapping[1] is a tool which facilitates the basic understanding of the processes in a system. The success of process based approach in manufacturing industries has prompted service researchers to apply the same technique to service industry.

## 2.1 Service

Services are a central part of our day to day life. Services can be found everywhere in our artificial world (apart from natural creations). Financial services (banks, insurance), distributive services (**energy**, public transport) and social services (medical, education) are the most commonly found examples of services. Services like physical products, require preparation, production, marketing and distribution. However, the line between services and products is not clear. Several researchers has attempted to define services for the last 30 years. The heterogeneity of service offerings has made it impossible to agree on a standard definition.

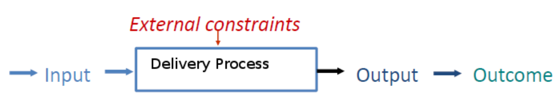


Figure 2.1: Block diagram of service system

The main stream service literature define services as activities with four basic characteristics (IHIP): Intangible, Heterogeneous, Inseparable and Perishable. Service offering is often an idea or promise made to a customer by the service provider. Knowledge transfer during the teaching event in a classroom is an example of intangible service offering. Customer preferences and needs make services heterogeneous. Generally, services are performed with customer participation either directly (health care) or indirectly (security). A health care event during the surgery is a good example of the perishable nature of services. Unlike manufacturing, service production is

[1]Process mapping is a graphical representation of the process that various stakeholders agree on and use as a tool for facilitating the improvement of existing processes and for designing new processes.

performed in open to accommodate customer needs and preferences in the productions. Customer involvement (providing inputs) in the service production process represents the inseparable nature of the services. An open production system is subjected to external constraints besides the internal constraints of the process. A block diagram of service system is shown in the Figure 2.1. Elements of service delivery system are listed bellow.

- **Inputs**: Typical inputs include customer needs and preferences, and, consumables like material and energy.
- **Delivery Process**: Different entities[2] and stakeholders[3] during the delivery process employ inputs to achieve the specific objective of the system.
- **Output and Outcome**: Conceptually output and outcome are different from a service engineering perspective. Processing of the inputs results output whereas specific objective of the service is the outcome. In the case of lighting (energy service), electricity is the output and illumination corresponds to the outcome.
- **Constraints**[4]: Like any other system services are also subjected to internal and external constraints.

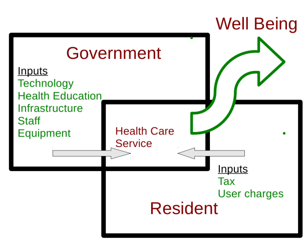


Figure 2.2: Public health service system

Services are like manufactured products. Service providers produce services to satisfy end-user needs using inputs like capital, labor with the association of other stake holders in the delivery process. Service is nothing but value **co-production** between multiple stakeholders including the end-user. The end-user is a co-producer in services. Public health care is a good example of value co-production. Citizens, as

[2]An entity is something that has a distinct, separate existence, though it need not be a material existence.

[3]Stakeholder is the one who has a share or an interest.

[4]A constraint is anything that prevents the system from achieving its objectives.

users of public health care contributing monetary resources to government through tax and user charges. Governments utilizes resources provided by end-users to create a health care service system as shown in the Figure 2.2.

## 2.2 Service Delivery Modeling

In manufacturing, managers plan and oversee the production process in order to achieve the objectives of the firm (profits). Likewise, service organizations also need to plan and oversee the service delivery process to accomplish their objectives. The main responsibility of service organization is to deliver **quality services** to the end-user by ensuring **accessibility** and **affordability**. Achieving this objective requires service management to ensure efficient utilization of available resources like capital, human resources and technology. The case of public health care demonstrates the importance of service management in the delivery process. Public health care employs a large number of staff ranging from cleaners to highly skilled surgeons overseen by the administration, who are also **stakeholders** in the health care. Primary, acute and emergency care constitutes the main **entities** of the health care system. In addition to main entities, health care requires other supporting entities such as diagnostic, cleaning and pharmacy services. Effective delivery of health care requires planning and managing the coordination between the different entities and stakeholders.

The service delivery process is an important element in service management. An excellent service delivery process satisfies the end-user needs and meets the strategic intentions of the organization. It is usually the result of careful design and the execution of a whole set of interrelated processes.[11]. Many services are complex involving different entities and stakeholders. They interact during the service delivery in order to achieve specific objectives. Often, poor service management results in failure to deliver services to the end user. The greatest **challenge** in service management is to improve the existing service delivery process as most of the services have evolved over time[5].

For improving the service delivery, building a conceptual and/or empirical **service delivery model** is a initial starting point. Various stakeholders in the process must agree with the developed model. Service delivery modeling is an exercise

[5]Service management is a new discipline.

that can be approached from three different, but complementary epistemological perspectives.[10]

- ***normative*** perspective according to upper levels of management or transactional environment which provides how services are thought or supposed to be delivered from a top management perspective. In simple terms, **service intentions** are represented and examined. Since intentions are not always carried out in practice, service process validation is subjected to maximum risk with this perspective.

- ***Hermeneutic*** (understanding) perspective is the second approach. It focuses on the experience of different stakeholders during the service delivery process. Interviews, brainstorming sessions or narrative analysis are used to generate a picture about the delivery process. Bounded rationality[6], selective perception[7] and limited visibility[8] of the individual stakeholder introduces a reliability risk in this approach.

- ***Positivistic*** perspective represents general service delivery characteristics such as flow, handovers, capacity utilization or throughput time. They are measured using observations and recorded data. This approach provides quantitative foundation for service delivery analysis. The risk of narrow focus and irrelevant analysis are involved in this approach.

A good service delivery model uses all three perspectives. Finally, several tools and techniques have developed to engineer service delivery in order improve existing services and to design new services [11]. They are:

- **Process mapping**: It is a graphical representation of process in system that various stakeholders and entities agree on and use as a tool to facilitate improvement. Process mapping or blueprinting is used to clarify and explicate the existing process and for designing a new process.

- **Walkthrough audits**: Most service organizations process customers. The customers assessment of the service is audited using a check list of questions. The key requirement of this approach is selection of the right attributes.

[6]The notion in decision making, the rationality of individuals is limited by the information they have, the cognitive limitations of their minds, and the finite amount of time they have to make decisions.

[7]It refer to any number of cognitive biases in psychology related to the way expectations affect perception.

[8]Stakeholders in the process have limited understanding or perspective about the outcome of the process.

- **Service transaction analysis**: Service element analysis is implemented with specific design tools along with walkthrough audit in service transaction analysis.

## 2.3 Process Mapping of Services

Process optimization is the main aim of managers or engineers involved in physical production. Process optimization strategies have been in practice from the early 20th century. Frank Gillberth pioneered process optimization using a technique known as the **process map** or **process blueprint** in 1908. He graphically described the process for optimizing brick laying process using 17 montions called "therbligs". Gillberth observed different methods of working by bricklayers and represented the work flow graphically using therbligs. He developed innovative tools and work procedures based on the graphical representation of existing work methods. These innovations included: scaffolding that permitted quick adjustment, shelves for bricks and mortar, and methods for getting the bricks and mortar to the bricklayers by lower paid laborers [13]. The net effect decreased the effort to 4 movements from 18. i.e., Therefore, the task was performed much more efficiently. [12]. The graphical representation of work flow (process) is called process mapping or blueprinting. Likewise, any process can be mapped. For example, buying a laptop can be mapped as every process involves number of steps as shown in Figure 2.3.

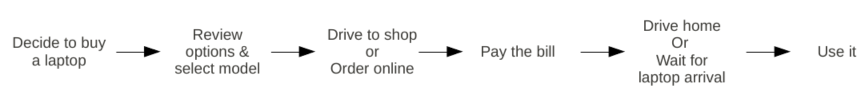


Figure 2.3: Process map of buying a laptop

**Process mapping** is a conceptual graphical tool that is used to ***understand, analyze and document processes and activities in an organization and assist in identifying opportunities for improvement*** [11]. A process map displays the sequential steps involved in converting a specific inputs to achieve the strategic intentions of the organization. Visual representation of the steps facilitate better understanding of activities and responsibilities for the entities & stakeholders involved. It documents the steps in a simple manner. The maximum benefit can be drawn from the process map if the graphical representation is more analytical. The analytical process map highlights bottlenecks, delays and inefficiency in the process. It can be used to identify the constraints that are preventing the system from achieving its strategic intentions. Therefore, process mapping can be used as a diagnostic tool for institutional analysis of an organization to identify constraints in order to facilitate improvement.

Visual representation of production process is straightforward in physical production. Unlike manufacturing, the service delivery process cannot be readily identified as they exhibit dynamic and interrelated characteristics. The service delivery process can be visualized based on their characteristics. The defining characteristics of a service delivery process are the intangibility of service offerings; customer induced variability in terms of quantity and quality; constraining lines of visibility, interaction, influence, and responsibility; and delivery constraints in terms of time and location. Service delivery process design, modeling, and improvement need appropriate conceptual or empirical tools to deal with these issues [14]. Process mapping is one such conceptual tool which can be used for analysis of a service system. The objective of process mapping is to provide a better understanding of the service delivery process and to identify institutional constraints. Service delivery analysis will provide the necessary inputs for building a process map representing the above mentioned characteristics.

| **Unit** | **Focus** |
|---|---|
| Task | Tact time, efficiency, quality, utilization |
| Process | Sequence, hand overs, process quality, inventory, time, capacity, repetition, process cost and value |
| Cross functional process | Cross functional hand overs, quality as defined by the next process |
| Governance | Resources, objectives, measurement, monitoring, rights, responsibilities, incentives and throughput time |

Table 2.1: Units of service delivery and their focus [10]

A molecular modeling approach is useful in service delivery (molecule) modeling for service delivery mapping very much in the way that atoms are connected in unique “molecular configurations” [15]. It allows identification of service entities (like atoms). It also offers a framework for identifying and visualizing interactions (electron bondings) between different service stakeholders (electrons) in a service entity. Based on such a molecular approach the smallest element of a service process is a task. Combinations of tasks constitutes a process. Different entities & stakeholders need to be mobilized in a service delivery process to achieve the specific objectives of the interaction. For example in health care, the diagnostic process needs the assistance of medical imaging or pathology departments, i.e. service processes are cross-functional between different entities & stakeholders. A cross-functional process environment requires governance or management to oversee the coordination to avoid delays and bottlenecks in the service delivery process. The different units of service delivery and their focus is summarized in the table 2.1.

From service delivery analysis, a analytical service delivery map is created by using basic flow charting techniques which describe activities, resource consumption, exchange and flow and level of involvement. A service delivery map can be arranged and elaborated from different perspectives. Selection of the right mapping tools maximize the benefits of the service delivery process map. Service delivery mapping conceptualization can be done with the following mapping tools.

- An **actor** (an entity or a stakeholder) perspective is used to highlight responsibilities and duties in service delivery. A rectangle is used to represent this perspective. The relative size of the rectangle represents the significance of the actor in service delivery.

- A **resource** flow and allocation perspective in the service delivery is represented by adjusting size of the flow chart representation.

- A **capacity** perspective identifies capacity utilization of each step in service delivery.

- A **time** perspective depicts service delivery along real timescale to highlight the elapsed time of the process.

- A **time value** perspective distinguishes value added time from non value added time.

- An **administrative** perspective highlights organizational boundaries, areas of authority and corresponding responsibilities.

- An **information** perspective separates information and material flows and pinpoints the information requirements and recording responsibilities for each step.

- A **movement** outlook displaying routes and distances traveled by objects of processes at macro level to satisfy service objectives.

- A **core** and **support** perspective aims at separating the core process contributing value to the customer directly.

A rich service delivery process map considers the above mentioned mapping tools and many more. However, mapping becomes a laborious exercise and complex considering more mapping perspectives. In practice, a few mapping tools should be selected based on an understanding of the objectives of the service delivery. Finally, ***the service delivery map should support the strategic intentions of the service organization***. The following example explains the service delivery mapping procedure with an example.

## 2.4 Example: Opening Student Account in Lloyds TSB Bank plc

Lloyds TSB bank, one of the oldest financial service institution in United Kingdom, started their operations in 1765. In early 2000 they were facing competition from other financial institutions during the rapid growth of information and communication technologies (ICTs) in financial services. They were constantly seeking new customers to strengthen their market position to sustain competitive advantage. They decided to focus on the student market segment, who will be the future working class in the country. Lloyds started investigating financial services offered by the bank to students. They found that opening a student account (OSA) was a laborious exercise from the student's perspective. In order to understand the existing service delivery process of OSA, they developed a process map representing delivery process steps from the viewpoints of a student and the provider (Lloyds TSB Bank plc). Interviews and observations were used to develop a first hand understanding of the service delivery. Service delivery process mapping was used to identify problem areas such as bottlenecks, delays and duplications. Service delivery map of OSA before service quality improvement is shown in the Figure 2.4. The investigative team used hermeneutic (understanding) and positivistic perspectives for the service delivery process mapping. Time and time value perspectives were used as service mapping tools. The investigative team identified the following problems areas.

- **Entrance and exit**: Students found it hard to access the bank during typical opening hours (9.00 a.m to 5.00 p.m) on weekdays.
- **Completing and submitting the form**: Often students were asking bank staff for assistance to fill in the forms. Further, illegibility of the handwriting of some students also proved to be a problem for the bank staff.
- **Queue**: Banks usually manage customers service by a first come, first served basis through a queue mechanism. This has negative effect on students.
- **Identification**: Unless students have two forms of identification with them, the process was delayed by a few hours or days.

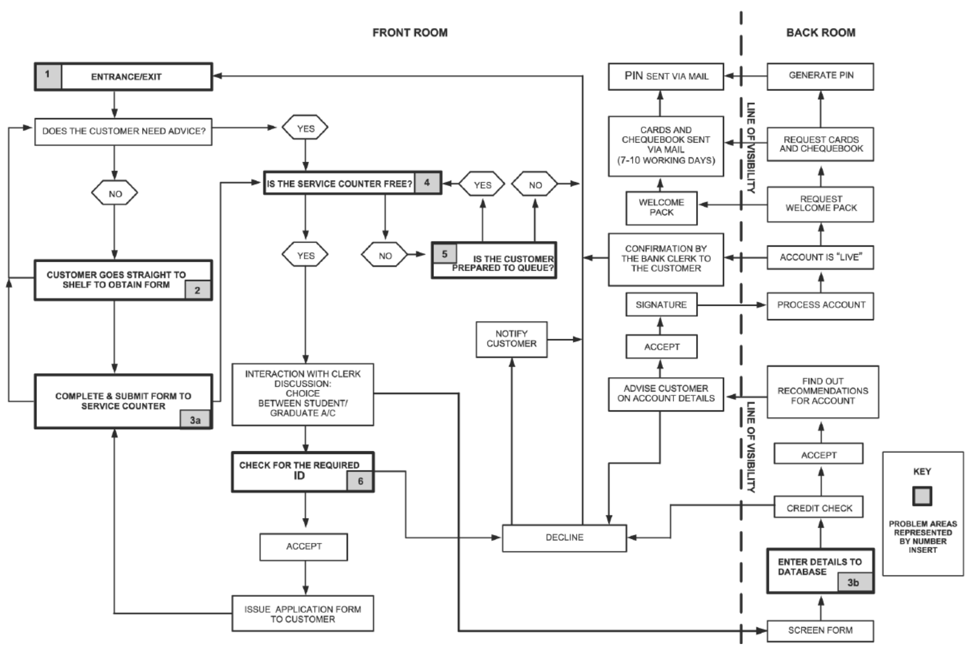


Figure 2.4: Service delivery process map of OSA before service quality improvement [16]

Through identification of the problem areas bank was able to develop an improved OSA process as shown in the figure 2.5. The improvements were listed below. The revised service delivery process does not completely solve all the problems, but it does address the problem of **non value added time**. In addition, it improved the bank's efficiency and productivity and students satisfaction.

- Financial services were offered through Internet, which would allow 24 hour banking services to the student.

- students as well as customer queries about the financial service were clarified at the service counter.

- Removal of paper based application enabled quick processing of applications. The clerk's interaction with the students (customers) offered more satisfaction. Further it provided a solution for the illegibility of handwriting in the earlier case.

- The fact, the requirement for two forms of identification was mentioned at the beginning of the interaction in order to save non value added time to students and the bank.

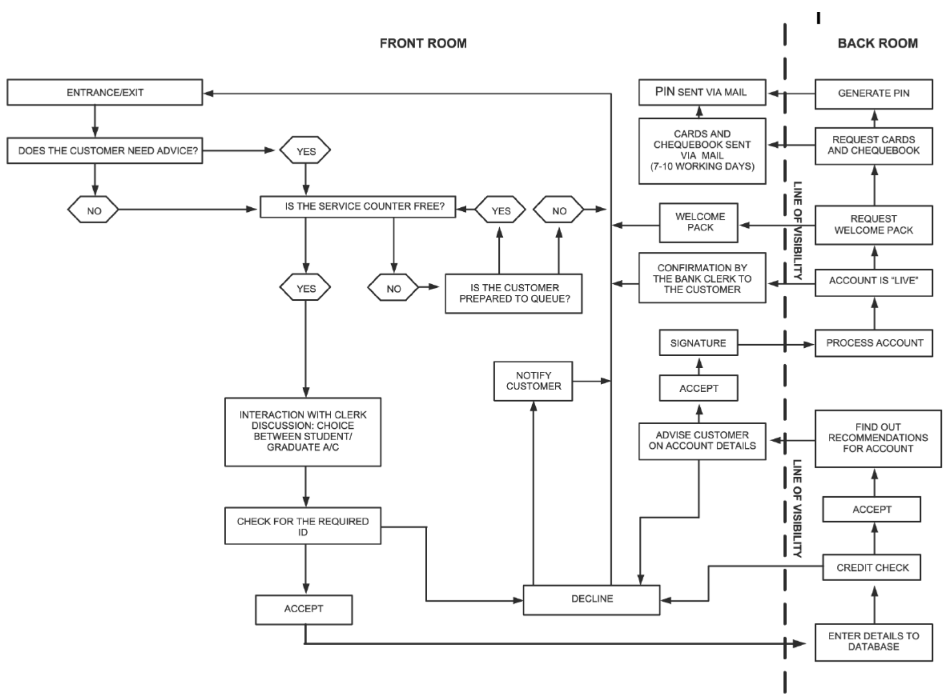


Figure 2.5: Process Map of OSA After Service Quality Improvement [16]

# 3 Methodology and Limitations

Service Science, Management, and Engineering (SSME) is a new interdisciplinary approach to understand, design, and implement complex systems. In these systems, different entities and stakeholders interact to achieve specific objectives and co-create value for each other. Service sectors such as banking, health, and Information and communications technology (ICT) are employing SSME methods to improve their service offering to customers. Further, SSME helped them to achieve a competitive advantage over other market players by using service delivery process optimization techniques. In this study, the importance of a decentralized energy service delivery process in developing countries from SSME perspective is understood and an institutional analysis is performed on service delivery.

## 3.1 Methodology

The thesis work is divided into five parts. SSME concepts discussed in the previous chapter are used to define energy service delivery in general in the first part (Chapters 4). In addition, conventional energy service delivery models are analyzed from energy service provider's standpoint using a governance process map to understand the importance alternate service delivery models in developing countries. The importance of decentralized energy service delivery to improve energy access in developing countries is discussed in the second part of the work (Chapter 5). The third part of work (Chapters 6 and 7) concentrates on decentralized energy service delivery models in India. Further, institutional analysis of different decentralized energy service delivery is performed using service delivery process mapping from the energy service provider's viewpoint. Results of a walkthrough audit in the case of market based decentralized energy service delivery is done in the fourth part of the study (Chapter 8). The last part of thesis is the conclusion. The two methods used in this thesis are explained below.

### 3.1.1 Process Mapping

Process mapping is a simple and inexpensive institutional diagnostic tool. It graphically represents the service delivery process in an institution that various stakeholders agreed upon. Process mapping is used to understand, analyze and document the processes and activities in an institution and assists identifying the opportunities for improvement. Process mapping is straightforward in the physical production. Unlike physical production, the process mapping of services delivery is an exercise and is usually done in three steps.

The initial starting point of the process mapping is to build a conceptual model. A conceptual model of energy service delivery for this study is approached from three different, but complementary epistemological perspectives. They are listed below.

**Normative perspective**: Energy service delivery according to upper levels of management, which provides how services were thought or delivered from the energy service provider's (ESP) point of view, is represented. In simple terms, the process of achieving energy service delivery objectives is represented from governance view. This perspective is used in the first four parts of this thesis work to understand different energy service delivery approaches.

**Hermeneutic (understanding) perspective**: This routine focuses on experiences of the stakeholders during energy service delivery. Interviews (personal, printed and web) and narrative analysis of stakeholders are used in this study for hermeneutic perspective. This perspective is used in the fourth part of the study.

**Positivistic perspective**: Transactional environment, monetary flow (external support and revenue), throughput effort (in the case of marketing, production, and maintenance during energy service delivery) and end-user inputs are observed using brainstorming sessions with the stakeholders in the energy service delivery process. This perspective is also used in the fourth part of the study.

After conceptualizing the delivery model, the second step is selecting the unit of analysis for analyzing the service delivery. For this study, governance and service delivery from ESP's perspective are selected for analyzing the services delivery. The governance process map from an ESP's point of view provides a basic understanding of service delivery and responsibilities of the ESP. In addition, it focuses on other stakeholders contributions during service delivery. The overall objective of other stakeholders is represented in the governance process map. Further, energy flow and energy service are visually represented. This governance process map is used in the first four parts of the study to analyze service delivery to the end-user from a governance perspective.

The process mapping of the service delivery process from the ESP's perspective analyzes throughput effort during the service delivery process, and monetary assistance and revenue from other stakeholders. The energy service delivery chain is conceptualized by the order of marketing, production and maintenance in this thesis supported by external assistance from other stakeholders. This mapping is used in the fourth part of the study for institutional analysis of decentralized energy services delivery.

The next step after selecting the unit of analysis is choosing service mapping tools for process mapping from the ESP's standpoint. They are listed below. The process mapping of service delivery is constructed in the thesis work using the following mapping tools.

- An actor outlook, which highlights responsibilities and duties of different stakeholders in energy service delivery. A rectangle is used to represent the actor. The relative size of the rectangle represents the significance of the actor energy service delivery.

- Throughput effort of ESP or implementation agencies in the case of public development and donor agencies, represents their effort at different levels during energy service delivery. The size of the arrow characterizes the relative effort of the ESP during energy service delivery.

- A resource outlook highlights monetary assistance and revenue, financial transactions and technology transfer during energy service delivery.

- An information outlook represents the flow of information to other stakeholders in the delivery process during energy services delivery.

- An administrative outlook emphasizes organizational boundaries of different service entities in energy service delivery.

### 3.1.2 Walkthrough Audit

Service performance for market based decentralized energy service delivery is evaluated using a check list of questions to understand the end-user's perspective. Questions for the walkthrough audit are framed to analyze service performance in three stages. The three stages are pre-service, during the service and after the service.

## 3.2 Limitations

The approach used in thesis work is conceptual and yet to be quantified. The process maps focuses only on the energy service provider's perspective. Perspectives of other stakeholders are not considered for process mapping. In addition, it is assumed that energy service delivery is a public service obligation in developing countries. The institutional analysis results are limited to decentralized energy service models receiving monetary support from development agencies. The walkthrough audit is performed in random without considering the statistical significance of the sample size. The work will be continued in the future to address the above mentioned limitation as part of the author's post graduate studies.

# 4 Energy Services Delivery In Developing Countries

Clean, efficient, affordable and reliable energy services are indispensable for quality of life. Developing countries in particular need to expand access to reliable and efficient energy services to reduce poverty and improve the health of their citizens. It also enhances productivity, competitiveness and economic growth [17]. This section discusses conventional energy services delivery in developing countries.

## 4.1 Energy Service

Energy is embedded in every product and service we consume. Energy is necessary even for day to day activities like cooking and lighting. However, end-users do not need energy itself or the energy produced by energy transformation devices, but rather the outcome offered by the energy. In general, outcome is offered by a combination of energy source, human and physical capital, and external environment. In the case of biomass based cooking, biomass is an energy source available in nature. Nature corresponds to the external environment. A three stone stove represents physical capital. The end-user's engagement in procuring biomass stands for human capital. Cooking is the energy service.

| **Energy Services** | |
|---|---|
| *Direct* | *Indirect* |
| Lighting | food |
| Heating, cooking, cooling | Shoes, shirts, clothes |
| Washing, ironing | Communication, exchange of information |
| Mobility, transport, etc. | Buildings, Vehicles, etc. |
| Drilling, sawing, etc. | Commercial goods |

Table 4.1: Classification of energy services [18]

Energy service can be defined as *"the outcome offered by an energy service provider by using the energy transformation system and other inputs with the direct or indirect participation of the end-user"* from a service engineering perspective. The **energy service provider** is an entity or a stakeholder who ensures delivery of reliable energy services with the participation of other stakeholders in the process. Broadly energy services are classified into direct and indirect energy services based on applications. Examples of direct and indirect energy services is shown in the table 4.1 [18]. Traditional and modern energy services constitute two types of energy services based on energy input and technology. Energy needs (outcome) satisfied by inefficient energy sources and technologies, are called traditional energy services whereas needs fulfilled using efficient energy sources and technologies, are called modern energy services. In principle, energy services require many more inputs like human and financial capital beside energy resources.

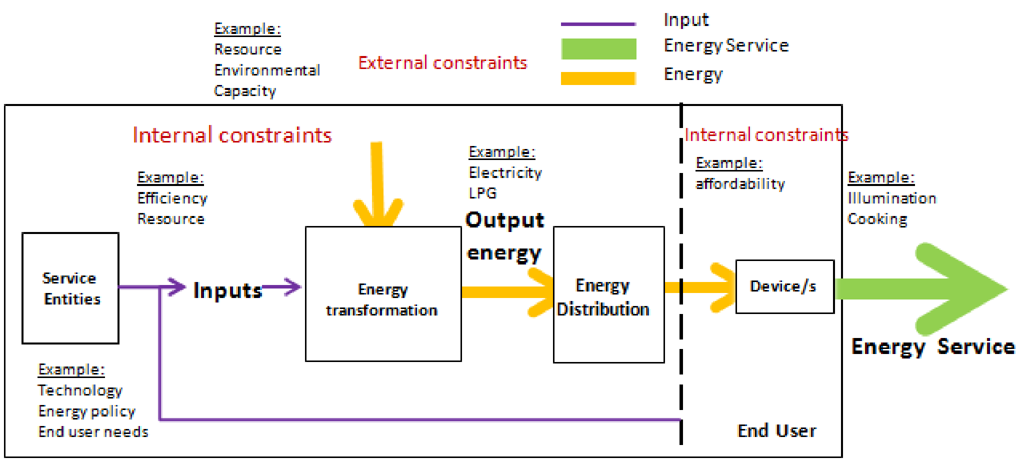


Figure 4.1: Energy Service System

An electric bulb (***device***) does not offer illumination (***energy service***) without electricity(***output energy***). Electricity need to be generated using primary energy and other inputs such as capital and technology. The **energy service provider** ensures a reliable electricity supply with the coordination of other service entities and stakeholders to the end-user by using an energy distribution infrastructure. End user exchanges electricity services with monetary inputs. As a ***co-producer***, the end-user specifies (directly or indirectly) his energy needs to the service provider. In addition, the service system is subjected to ***internal & external constraints*** like affordability, efficiency and sustainability. The block diagram of energy service system is shown in Figure 4.1. Before discussing energy services delivery in developing countries, it is interesting to study the economic characteristics of energy sources.

## 4.2 Economic Characteristics of Energy Sources

Energy sources can be classified into two types based on macro economic concepts. They are non-commercial and commercial energy sources. [19]. Non-commercial energy sources are traditional energy sources like biomass and animated power. Commercial energy sources are traded commodities on macro level like electricity and petroleum. Non-commercial energy sources demand decreases with an increase in income level of the end-user [20]. Therefore non-commercial energy sources are **inferior goods** based on consumer theory [21]. On the other hand, commercial energy sources are **superior goods**. Their demand increases with an increase in income levels as higher income enhances the affordability of commercial energy sources like electricity. Further, non-commercial energy sources are substitutes[1] for commercial energy sources particularly in developing countries, i.e. the demand for non-commercial energy sources like biomass increases with an increase in the price of Liquid Petroleum Gas (LPG) at a constant income level. The simplified economics characteristics of energy sources are shown in Figure 4.2.

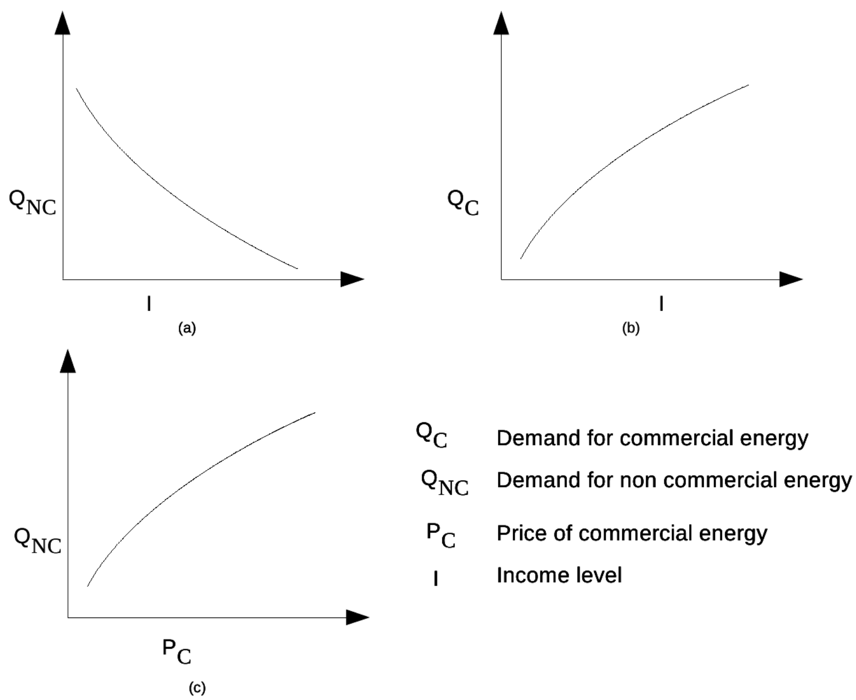


Figure 4.2: (a) Inferior characteristics of non-commercial energy. (b) Superior characteristics of commercial energy.(c) Demand for non-commercial energy with price variation of commercial energy

## 4.3 Energy Services Delivery in Developing Countries

Throughout the history mankind mined and manipulated natural resources to extract energy. Before industrial revolution **non-commercial** energy sources satisfied

[1]Substitutes are the goods with positive cross elasticity of demand.

the energy needs. Biomass available in the neighborhood was used for household activities like lighting and heating. Animated power supplied mechanical energy. The industrial revolution initiated a series of changes in the way we extract and consume energy. In this transition, non-commercial fuels were replaced gradually by commercial fuels which offered high energy density. Energy services using commercial (fossil) fuels enhanced production capacities in industrial firms and respective economic activities in the society. This transition also altered energy services pattern in households. Households also started using commercial energy sources like electricity and LPG for energy services. Traditional energy services were gradually replaced by modern energy services. This transition is still unraveling throughout the developing world.

It is increasingly clear that accessible, efficient and reliable energy services are important to support economic as well as social development. By the same token, chronic supply shortages and inefficient technologies have the potential to undermine socioeconomic development. The following discussion explains in detail, about two dominant energy services delivery models in developing countries based on the economic characteristics of the primary energy at the end-user level.

### 4.3.1 Traditional Energy Services Delivery

A typical traditional energy service delivery model is shown in the figure 4.3. Non-commercial energy sources satisfy the end-user's energy needs in traditional energy service. In the case of cooking (energy service), the end-user and nature are two service entities in traditional energy services delivery. The availability and accessibility of natural resources are the major internal constraints besides efficiency of the energy transformation process. The external constraints include sustainability, productivity and competitiveness. In traditional energy services delivery, the end-user acts as a service provider and customer himself. This could be explained by considering the case of cooking, wherein the end-user procures biomass from the neighborhood and uses it as a fuel for cooking.

The typical input for traditional energy services delivery is the **time** spent by the end-user for gathering non-commercial energy sources. The widespread use of the energy sources can result in the scarcity of local supplies in populated areas. This forces end-users to spend hours gathering energy sources from further afield. In India, end-users spend two to seven hours of each day for collecting of fuel for

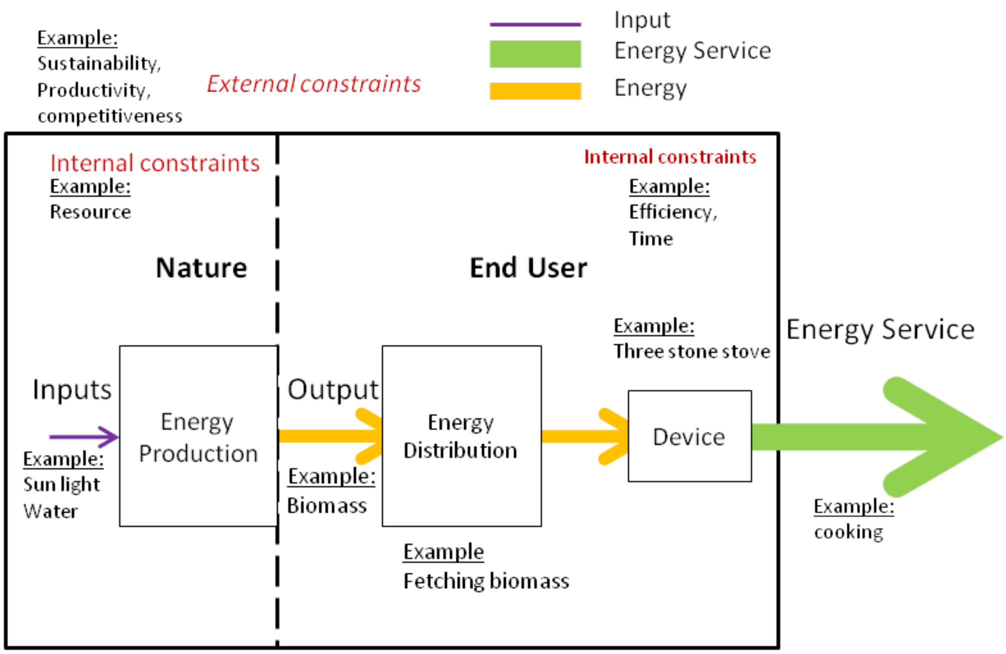


Figure 4.3: Traditional Energy Services Delivery

cooking [20]. Since time is a critical input for productive activities like education and agriculture, this scenario will have a profound impact on the quality of life and development.

The international energy agency (IEA) estimates that **2.5 billion** people in developing countries depends on inefficient energy sources like biomass for basic energy needs [22]. The number could be more than 3 billions according to the estimates of the United Nations Development Program (UNDP) and the World Health Organization (WHO) [17]. Enduring dependency on traditional energy services is one of the key attribute for poverty in developing countries [20]. Further, upholding practices will have catastrophic effects on the environment. Macro level implications of dependency on traditional energy services in the developing countries are listed below.

**Quality of life**: Energy is an essential input for quality of life. the figure 4.4 depicts the relation between per capita household commercial energy consumption and the Human Development Index (HDI) rank [2] [23]. It clearly indicates that a low level of commercial energy consumption leads to a poor quality of life in developing countries.

[2]The statistic composed from data on life expectancy, education and per capita GDP collected at the national level by UNDP

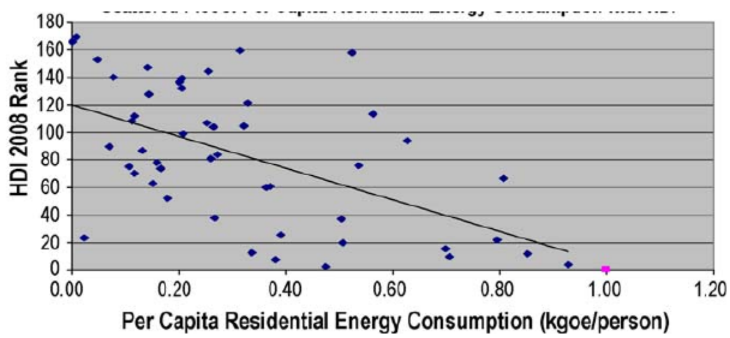


Figure 4.4: Scattered plot of Per Capita Energy Consumption with HDI ranking [23]

**Economic growth**: Energy is the driving force behind all economic activities. Traditional energy services limit the efficiency and productivity of the economic activities. Thus, enduring dependency on traditional energy services will hamper economic growth prospects.

**Health**: Energy and health are closely linked together. Traditional energy services cause indoor pollution in inadequate ventilating spaces. This will have profound implications on the health of end-users. WHO estimates that the impact of indoor pollution is a major public health issues in developing countries.

**Environmental sustainability**: In the case of traditional energy services, environment is subjected severe stress with increasing population in developing countries. Over dependency on natural resources like biomass is disturbing environmental sustainability through deforestation, air pollution and global warming.

Literature explains the enduring dependency on traditional energy services in developing countries using an **energy ladder** [1]. The energy ladder primarily attributes income level (affordability) to the selection of fuel and energy technologies. Low income groups tend to use inferior energy sources (non-commercial energy sources) like biomass for primary energy needs and inefficient technologies like the three stone cook stove. Users ascend the energy ladder with an increase in income and move to modern energy services which require superior energy sources like electricity and LPG. Energy transition of households with increasing income is shown in Figure 4.5. Energy ladder literature has attributed a relatively low degree of importance to infrastructure, relative fuel and technology cost and reliability when compared with **income** in the case of traditional energy services [24].

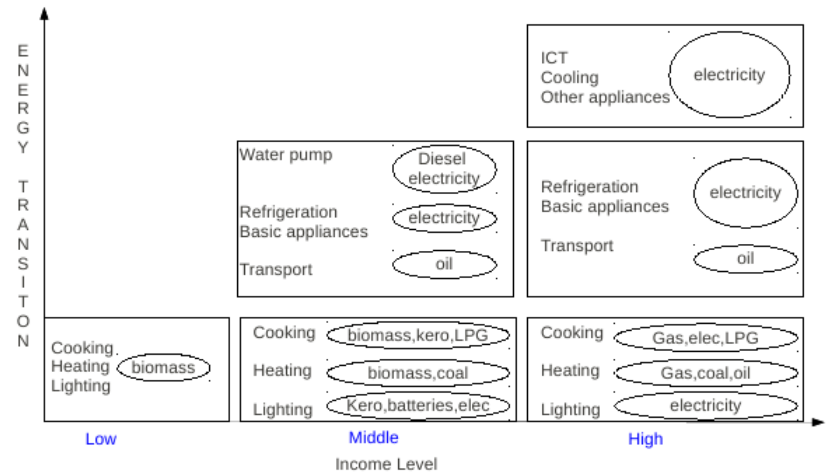


Figure 4.5: Transition to modern energy services with increase in income level of households [20]

### 4.3.2 Modern Energy Services Delivery

The modern energy service delivery model is shown in Figure 4.6. It favors centralized energy service delivery owing to economies of scale and promotes fossil fuels. Energy extraction, production and distribution facilities constitute the infrastructure of energy services delivery. Capital & revenue is an important entity of energy service production. The public economy stimulates the energy service system through energy subsidies. These subsidies are mainly intended for promoting technological developments or used as a policy instrument for enhancing energy service access. Energy policy is a crucial entity of energy service delivery. It provides vital information to various entities and stakeholders in the service delivery process. Economic activities enhance the end-user's capacity to participate in modern energy services. The transactional environment[3] exists between various entities and stakeholders in the service delivery process. Often, the service provider is an entity in energy service production. In a monopolistic market, the energy service provider is responsible for the entire energy service delivery chain.

Unlike traditional energy services, modern energy services delivery involve complex monetary and operational transactions. The service provider ensures energy service provision to the end-user with the assistance of other stakeholders and entities in the service delivery process. In traditional energy services, the end-user performs energy extraction and distribution to realize energy services. In modern

[3]Exchange environment involving resource such as information, for distinguishing them from the products responsibilities and monetary.

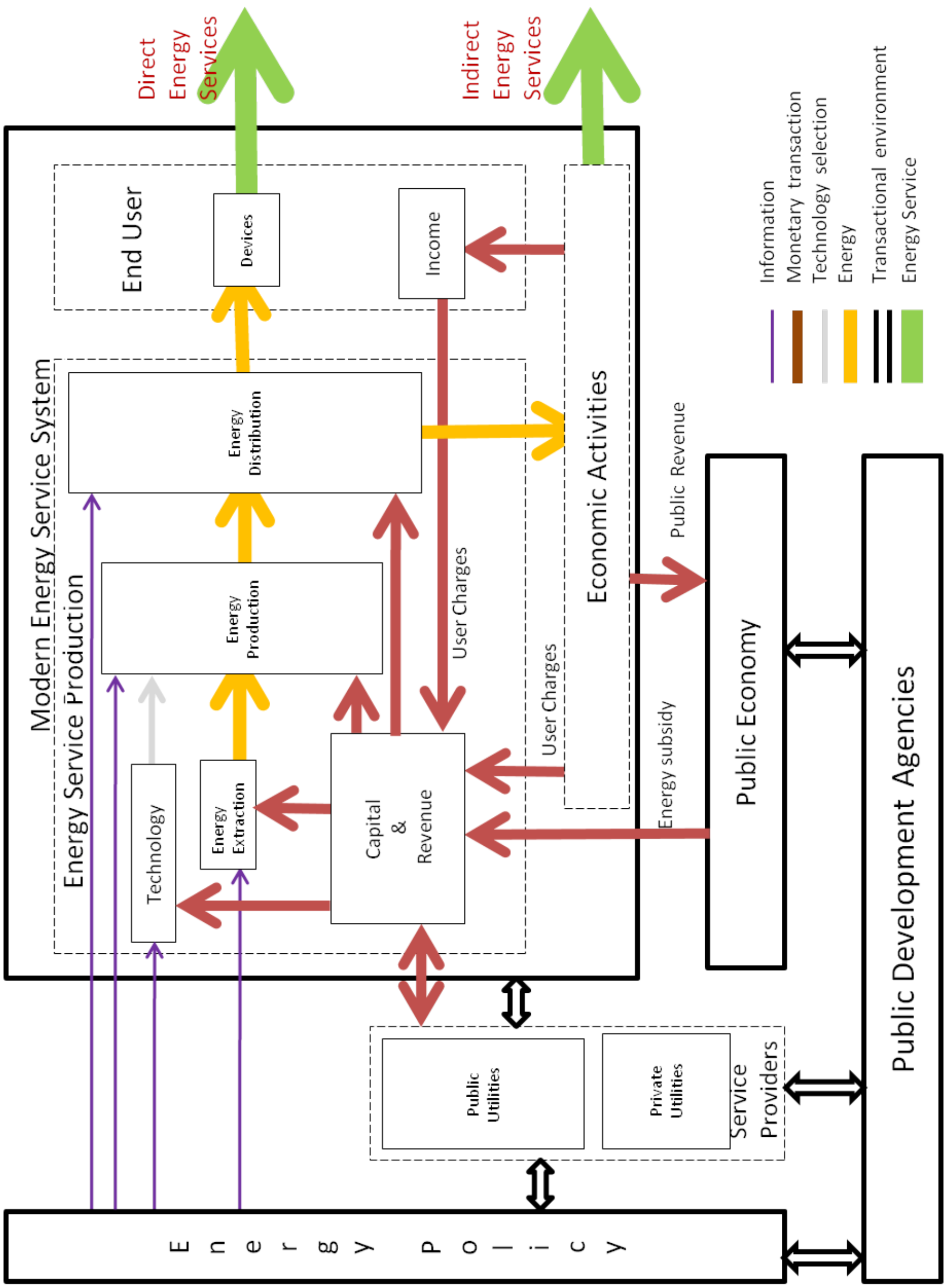


Figure 4.6: Centralized Modern Energy Service Delivery

energy services, other stakeholders perform the activities carried out by the end-user unlike traditional energy services. This relieves valuable time and effort required by the end-user in the case traditional energy services.

Developing Countries differ widely with respect to access to modern energy services. Access is more limited in the Least Developed Countries (LDCs) and Sub Saharan Africa (SSA). In developing countries, more than 40% of people rely on modern energy services[4]. However, in LDCs and SSA, only 9% and 17%, respectively, have access to modern energy services. 72% of the population in developing countries have access to electricity [22]. In the case of LDC and SSA it is 21% and 26% respectively. 33% of the population in developing countries use gas (mostly LPG) for cooking, but less than 10% in LDCs and SSA have access to gas for cooking.[5]

Table 4.2: Notable power shortages since 2000 in developing economies [26]

| **Country** | **Vintage** | **Cause** |
|---|---|---|
| Tanzania, Kenya | 2001 | Drought |
| Brazil | 2001–2002 | Drought, sector reform, insufficient investment |
| Dominican Republic | 2002– | Financial blackout |
| China | 2004–2007 | Very rapid demand growth, deteriorating load factors, insufficient investment |
| Bangladesh | 2005– | Demand growth and lack of investment |
| Tanzania | 2006– | Drought, depleted reservoirs, demand growth |
| Uganda | 2006– | Drought, insufficient investment, demand growth |
| South Africa | 2007 | Demand growth, lack of investment & coal shortages |
| Vietnam | 2007 | Very rapid demand growth |
| Rwanda | 2006– | Insufficient investment, demand growth |
| Ghana | 2006– | Insufficient investment, demand growth |
| Pakistan | 2007– | Rapid demand growth and lack of investment |
| Ethiopia | 2008– | Delay in commissioning of Tekeze Hydro Plant, drought and demand growth |

A reliable energy supply is a key ingredient to benefit from modern energy services beside efficient technologies. The present situation is not satisfactory in many developing countries. It can be characterized by persistent energy shortages and inefficient technologies. Resource (financial, operational, natural and technical) constraints, energy policies and substantial increase in demand are major factors

[4]Energy services using modern fuels. Modern fuels refer to electricity, liquid fuels, and gaseous fuels, such as LPG, natural gas, and kerosene.

accountable for energy shortages. Energy service providers are under severe stress in many developing countries due to energy shortages. The shortage is chronic in many developing countries. Notable electricity shortages are listed in Table 4.2. Often, energy rationing is used to address shortages in many developing countries.

Energy efficient technologies entail positive and multiple benefits for stakeholders involved in the energy service delivery process. Such technologies conserve natural resources at the supply side. Further, these technologies also reduce environmental pollution and the carbon footprint of the energy sector. On demand side efficient technologies reduce the operating cost of energy services to the end-user. It is a daunting challenge to achieve significant and sustained benefits from energy efficient technologies in developing countries. Th capital cost associated with them is the main barrier besides institutional policies. [25]. The macro level barriers of universal access to modern energy services delivery in developing countries are listed below.

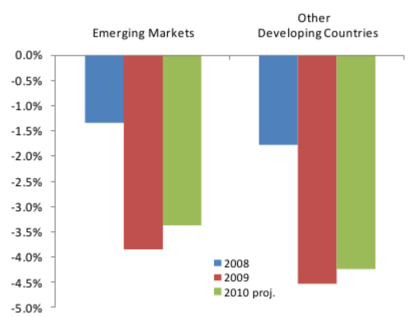


Figure 4.7: Fiscal deficits (% of GDP) [27]

**Financial constraints**: Energy service delivery require gigantic infrastructure facilities for production and distribution of modern fuels like electricity and LPG. Inadequate infrastructure facilities are major factors for limited accessibility and the unreliability of energy service delivery in developing countries. Infrastructure deployment is a capital intensive process. Adequate financial resource allocation is a difficult task in the case of state-owned utilities due to increasing fiscal deficits in developing countries as shown in Figure 4.7. In addition, private sector investments are relatively insignificant due to financial and regulatory impediments in those countries.

**Technology constraints**: Although various energy technologies are available in the global market, they remain beyond the reach of many developing countries.

**Energy subsidy**[5]: Energy subsidy is a common practice in many developing countries. In 2005, a total of US$220 billion spent on energy subsidies in the twenty largest developing countries. [2]. Energy subsidy remains a chronic problem in many developing countries due to populist policies. It creates a serious financial burden for the state, which confines further investments to enhance capacity and quality. Nevertheless, better-off households (especially urban population) often enjoys the benefits of energy subsidies than their counterparts. In some cases, benefits may not even reach the poor at all. The case of LPG in India demonstrates the exploitation of government subsidy by better-off households [28].

**Market regulation**: Energy service delivery chain is dominated predominantly by the state after world war II. Market deregulation[6] started after th 1973 energy crisis in industrial countries to promote competition. Since energy policies are still bound by **public service**[7] obligations, the progress towards market deregulation is still unraveling in many developing in countries unlike developed countries where they are **market driven**.

**Operational constraints**: Energy service production favors *centralized production and distribution* of energy owing to **economies of scale**. This approach limited energy service access partially or completely to the rural population (especially "last mile") and necessitates enduring dependence on traditional energy services. In 2007, 30% of urban dwellers in developing countries lack access to modern energy services whereas in rural areas it is 81%[5]. Further, the low income of a majority of households constitutes another operational challenge for the policy makers besides the last mile. The Deepam scheme implemented in India testifies to the above mentioned operational challenges. The **strong income elastic nature** of LPG has resulted in continued reliance on biomass as the primary fuel among the majority of Deepam beneficiaries, especially in rural areas [29].

[5]IEA defines energy subsidies as any government action that concerns primarily the energy sector that lowers the cost of energy production, raises the price received by energy producers or lowers the price paid by energy consumers.

[6]the removal or simplification of government rules and regulations that constrain the operation of market forces.

[7]usually used to mean services provided by government to its citizens, either directly (through the public sector) or by financing private provision of services.

**Energy demand**: Developing countries have been experiencing high economic growth since early 2000. The GDP growth projections of developing economies are shown in Figure 4.8 [30]. Realizing this growth demands reliable energy service provision. However, energy demand growth often exceeds the incremental capacity of the energy service infrastructure. The mismatch can be mainly attributed to the financial constraints of the energy service providers in general along with inadequate energy policies.

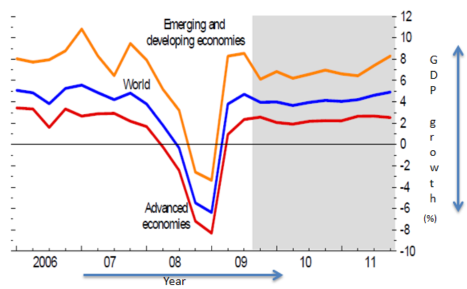


Figure 4.8: GDP growth projections (2006-2011) [30]

**External constraints**: Global warming[8], fossil fuel resource (like coal and oil) constraints and barriers of Renewable Energy Technologies (RET) are major external constraints of centralized energy services delivery. Excessive emission of Greenhouse Gases (GHG) causes global warming through radiative forcing[9]. The energy Sector accounted for 61% of total GHG emissions in 2005 as shown in the figure 4.9 [31]. This can be attributed to profound dependency on fossil fuels as shown in the figure 4.10. Mitigating global warming requires multiple approaches such as increasing energy harvesting from renewable sources, Carbon Capture and Storage (CCS)[10] and energy efficiency measures which are further capital intensive.

The World Energy Outlook (WEO) 2007 claims that energy generated from fossil fuels will remain the major source and is still expected to meet about 84% of th energy demand in 2030 [33]. The uncertainty surrounding the future supply of

[8]Global warming is the increase in the average temperature of Earth's near-surface air and oceans since the mid-20th century.

[9]Radiative forcing is a concept used for quantitative comparisons of different human and natural agents in causing global warming.

[10]It is process of capturing carbon dioxide from large point sources such as fossil fuel power plants, and storing it in such a way that it does not enter the atmosphere.

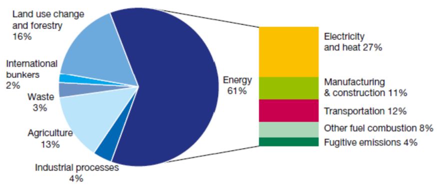


Figure 4.9: Global GHG emissions in 2005 [31]

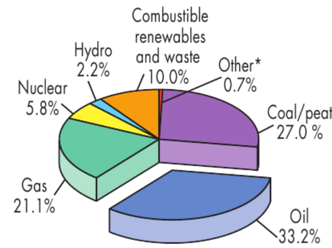


Figure 4.10: World total primary energy supply by fuel in 2008 [32]

fossil fuels is causing fluctuations in the energy trade. This volatile situation is effecting the energy security of importing countries as energy alternatives are in the development stage.

Renewable energy sources have a theoretical potential to satisfy energy needs. In addition, they offer solutions to global warming and energy security. However, their potential is limited in centralized energy services delivery as renewables exhibit dispersed and modular characteristics besides the institutional and technical constraints of RET.

## 4.4 Summary

Energy service access in developing countries can be characterized by:

- Enduring dependency on traditional energy services
- Unreliable modern energy services
- Inefficient technologies
- Widening gap between energy needs and supply
- Inadequate energy policies

In many developing countries, th traditional centralized energy service delivery model has not been sufficient enough to satisfy the energy needs in spite of ambitious policies and assistance from development institutions like the World Bank. Further, the primary energy needs of the world will grow by about 45 percent from 2006 to 2030 based on IEA estimates. About 87 percent of this growth is expected to occur in developing countries [34]. Therefore, adequate measures are necessary to improve energy access. Such measures must include encouragement for decentralized energy services. Decentralized energy services can fill the gap created by centralized energy services in rural areas, especially last mile. Further, in urban areas they have the potential to supplement centralized energy services.

# 5 Decentralized Energy Services Delivery in Developing Countries

Currently, primary energy is transformed into the final form of energy in large centralized facilities, such as thermal power plants and oil refineries. These plants demonstrate excellent economies of scale, but usually transmit energy over long distances for distribution. Most energy production systems are built this way due to a number of economic, health, logistical, environmental, geographical and geological factors. For example, coal power plants are built away from cities to prevent their heavy air pollution from affecting the populace. In addition, such plants are often built near collieries to minimize the cost of transporting coal. However, this approach has not been able to satisfy energy needs of large portions of rural inhabitants, especially the last mile. In the case of urban areas, centralized energy production need to be supplemented to improve reliability in developing countries. Decentralized Energy (DE) production has the potential to satisfy rural energy needs as well as capacity to supplement centralized energy production in urban environments.

## 5.1 Decentralized Energy Services

Energy service provision by transforming primary energy to useful form, at or near the point of use, irrespective of size, technology or fuel used is known as DE service. In DE services, local abundant energy sources are used for energy harvesting. The delivery of DE services differs on the extent of decentralization in developing countries. At household level DE services, energy satisfies only local needs. In the case of industrial level decentralization, apart from local needs, excess energy is supplied to the distribution network. Nevertheless, in this thesis the discussion about DE services is limited to household level, i.e. stand-alone systems. From this point, stand alone DE systems or services are referred to as DE systems or services.

DE systems are more suitable for rural areas, especially the last mile. In urban areas they can supplement centralized energy systems to provide energy security to the end user. The decentralized energy service system is shown in Figure 5.1. Common inputs of the DE system are capital, technology and primary energy. Local abundant energy sources are used as primary energy sources to minimize the operating cost. The energy transformation system converts primary energy to a more useful form of energy. Operational capacity of the energy transformation system depends on local (end-user) energy needs. In addition, the availability and energy density of the primary energy source also affects operational capacity of the energy transformation system. In the case of a simple standalone Solar PV Home System (SHS), a Photo Voltaic (PV) panel and battery constitutes the energy transformation system. The PV panel converts solar energy to electrical energy. Excess electrical energy is stored in the battery and used for backup on cloudy days. The operational capacity of SHS depends on the energy needs (total connected load) of the end-user and backup capacity requirement. Typical inputs for SHS are capital and technology. Different energy sources that support DE service delivery are listed in Table 5.1.

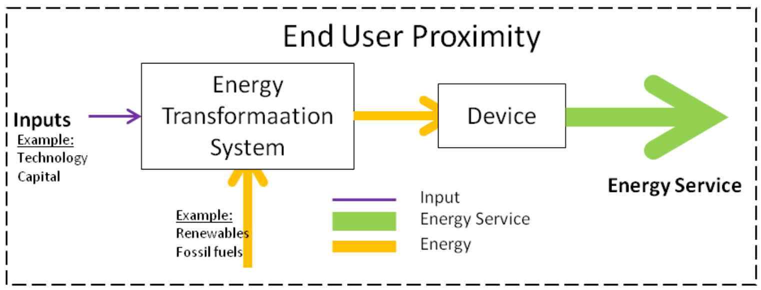


Figure 5.1: Decentralized Energy Service System

Table 5.1: Comparative description of different energy sources that support decentralized energy services

| Energy | Features |
|---|---|
| Solar energy | It is suitable for last mile or rural energy needs. The biggest barriers is high upfront cost of the technology |
| Biogas | It can be used for cooking or generating electricity. Reliability depends on availability of biowaste. |
| Producer gas from biomass | Biomass gasifiers are used to generate electricity. It is best suited for community based energy services. It requires daily maintenance. |
| Small and mini hydro power | They are best suited for providing energy access in mountain areas, where water resources are available. Reliability is an issue due to seasonal variations. |
| Liquid fossil fuels | Technology is mature in the case of liquid fossil fuels. However, they are non-renewable resources and require distribution channels. |
| Biofuels | Biofuels have potential to stimulate rural development by creating employment opportunities. Current international approaches might lead to conflict with food security in developing countries. |

Source:[35], [36], [7], [37] and [38]

Technology is not a single unit in DE services from the end-user's perspective. In the case of SHS, the PV panel, battery, charge controller and electrical bulb constitute the main technologies. Thus, realizing the potential of DE services requires accessible and affordable technologies ranging from small electric bulbs to energy transformation systems. Further, they should improve the productivity of the end-user. However, the greatest challenge is to bridge the existing gap between the technology providers and the end-users in developing countries. The case of an improved cook stove (ICS) illustrates the gap in developing countries. ICS is a simple technology. It is primarily aimed at improving the energy efficiency of biomass burning and eliminating the smoke from the kitchen environment. The importance of ICS was identified during the early eighties [39]. Based on IEA estimates in 2007, Fewer than 30 percent of people in developing countries who rely on solid fuels for cooking (i.e., traditional biomass and coal) use improved cooking stoves. The scientific literature attributes affordability and accessibility as the main factors behind the technology gap [6].

## 5.2 Decentralized Energy Services Delivery

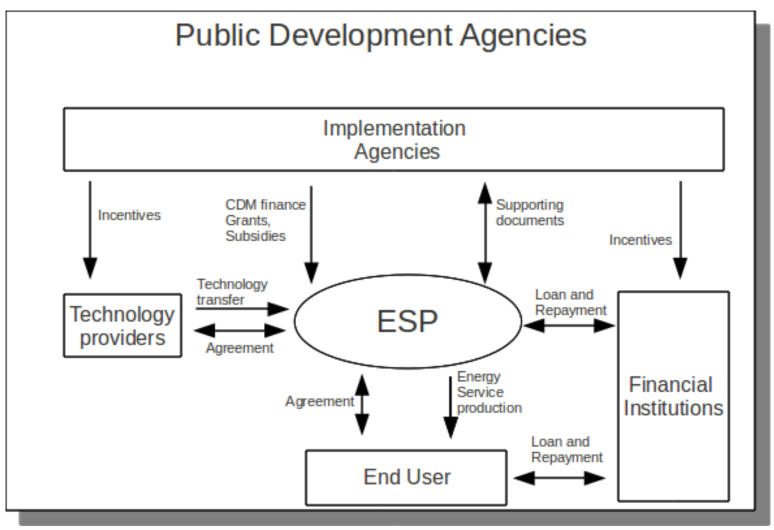


Figure 5.2: Simplified Institutional Framework of DE Service Delivery Model

Energy service delivery patterns are shaped by the behavior of a large number of actors or stakeholders, each of whom has to make many decisions to fulfill their responsibilities in the delivery process. End-user behavior is influenced by his resources (such as monetary and information) and preferences at a lower level. Further at macro level, energy policies put forward by public development agencies provide vital information to service entities or stakeholders. Energy services delivery is a complex process due to the involvement of various entities and stakeholders at different levels. In the case of DE services, the degree of complexity increases further as end user needs and resources are accommodated. A simplified institutional framework of DE service delivery is shown in Figure 5.2. Responsibilities or roles of different entities or stakeholders are listed bellow. Different participants of DE service delivery are listed in Table 5.2.

**Public development agencies** provide institutional assistance to ESPs and other entities or stakeholders. In addition, they tabulate energy policies for enabling service delivery to the end user.

**Implementation agencies** coordinate between public development agencies and other entities or stakeholders.

**Technology providers** need to ensure availability of affordable, efficient and reliable technologies.

**Financial institutions** facilitate support to ESPs and end users.

**Energy Service Provider** (ESP) has the primary objective is to ensure reliable energy services delivery to the end user with the assistance of other stakeholders in the delivery process. Further, ESP acts as an interface between other entities and the end-user. In this process, he creates *value* to them.

Table 5.2: Different participants in decentralized energy services delivery

| | |
|---|---|
| Public development agencies | State & provincial governments, United Nations and World Bank |
| Implementation agencies | Nodal agencies of respective development institutions |
| Financial institutions | Micro finance institutions (MFIs), private equity and commercial banks |
| End user | Household, small community and a village |
| Energy service providers | Donor community, development agencies and private entrepreneurs |

Decentralized energy services delivery can be differentiated based on institutional and end-user level in addition to the revenue model as shown in Figure 5.3. At institutional level, public development and donor agencies deliver DE services in developing countries beside the market. Household, community and block levels constitute three types of DE service delivery models at the end-user level. Based on the revenue model, two distinct energy service delivery models are end user ownership and pay for service. This study primarily focuses on institutional level DE services delivery in developing countries. The market approach is studied in detail based on the revenue model.

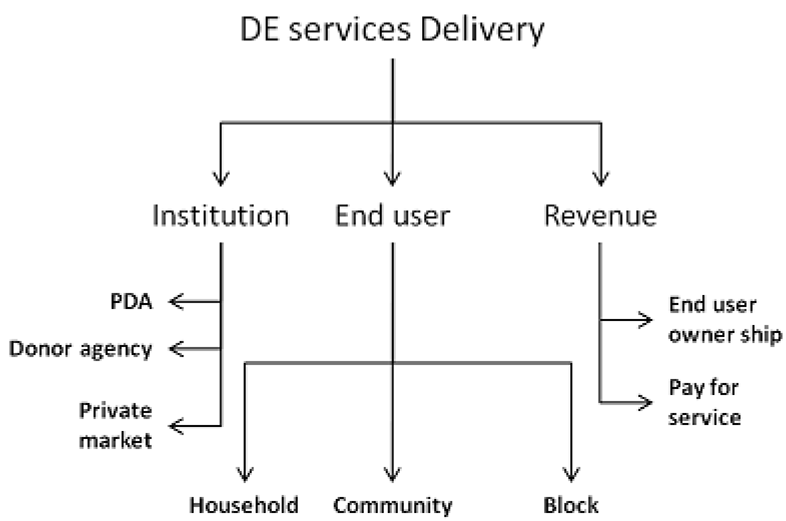


Figure 5.3: Classification of DE services delivery

Research studies related to decentralized energy services delivery can be mainly divided into two categories. They are development perspectives and techno-economic analysis. The development perspective identifies the explicit link between energy service and development in developing countries. In addition, the importance of decentralized energy services delivery for promoting sustainable development is mentioned. [4]. Techno-economic analysis evaluates technical options for decentralized energy services delivery in terms of cost sensitivity and technical efficiency. Further, it emphasizes the affordability of the end user. [[7],[6],[8]].

At institutional level, DE services delivery is gaining momentum in developing countries. It is in the early stages of evolution. Delivery models need to analyzed from an institutional perspective besides the earlier research methods discussed in the above paragraph for promoting DE services delivery in developing countries.

Investigation from institutional perspective is important at this stage as it provides better understanding of DE services delivery to the stakeholders and to identify strengths and constraints of different delivery models. Further, it may quantify the actions required to strengthen DE services. Different DE service delivery approaches in India at the institutional level are considered in the next chapter to understand the service delivery process in developing countries. Institutional analysis of DE services delivery in developing countries is performed using the process mapping technique discussed in the second chapter of this thesis.

## 5.3 Importance of Decentralized Energy Services Delivery in Developing Countries

**Rural energy needs**: With a centralized approach, transition to modern energy services is unraveling far more slowly in the rural areas of many developing countries. This can be attributed to the operational and resources constraints discussed in the previous chapter. The case of electricity access in South Asia and SSA testifies to the marginalization of rural areas (Table 5.3). Addressing energy marginalization in rural areas requires an alternative solution to centralized energy delivery. Decentralized energy delivery can provide the solution to address these rural energy needs, since the needs are small in absolute terms.

Table 5.3: % of population having access to electricity in South Asia and SSA

| Region | Year 2008 | |
|---|---|---|
| | Urban | Rural |
| South Asia | 60.2 | 48.4 |
| Sub Saharan Africa | 57.7 | 22.7 |

Source:World Energy Outlook, 2008

**Sustainable Development**: Eight Millennium Development Goals (MDGs) were adopted in 2000 by the United Nations [40]. Energy is the key ingredient for achieving these goals. The recent report by the IEA with the association of UNDP specifies the importance of decentralized energy services delivery in developing countries to achieve MDGs. [41]. Based on this report decentralized energy services are expected to satisfy 70% of household energy needs in rural areas of developing countries.

**Renewable energy technologies**:The centralized energy system was not designed to operate on renewable energy sources. It evolved to exploit the characteristics of fossil fuels. On the other hand, renewable energy sources exhibit very different characteristics to fossil fuels. Embedding renewable energy technologies to centralized systems is a complex and difficult process due to the very nature of centralized systems. On a smaller scale, however things look a little more optimistic because of modular nature of renewable energy sources. [42]. Therefore, decentralized energy services have the capacity to capitalize on renewable energy technologies.

A technology is not a product, often far from it, and its value is context driven; the key context is the product, applications, and markets [43]. The key context of renewable energy technologies (RETs) is market diffusion. At present, technology push[1] policies are being used to promote renewable technologies for market demonstration. On the other hand, successful diffusion of RETs require market pull[2] initiatives, which requires strategic deployment policies. Failure in doing so might lead to a Technology Valley of Death of RETs [44]. The theoretical demand of DE services in developing countries can supplement the existing strategic deployment policies that are intended for market diffusion of RETs.

**Demand-supply gap**: Failure of centralized energy service delivery resulted in a wide gap between demand and supply in many developing countries. The gap is widening further as a result of increasing population and growing aspiration of better-off households. This gap can be minimized with DE services delivery. In addition, DE service delivery reduces the stress on centralized energy services delivery in developing countries.

**Economy**: Small and medium enterprises play a key role in delivering DE services owing to the dispersed nature of business opportunities. These local business opportunities create local employment in developing countries. Thus, the promotion of DE service delivery at micro level stimulates local economic activities and at the macro level strengthens the economy.

**Market deregulation**: The energy service sector is subject to public service obligations in many developing countries, which lead to tight market regulation by the state. These tight regulations have resulted in economic hardship for energy service providers and discouraged the market, in the case of the centralized energy service

[1]A technology push implies that a new invention is pushed through R&D, production and sales functions onto the market without proper consideration of whether or not it satisfies a user need.

[2]Increasing in private investments to capitalize on identified market needs.

delivery approach. Deregulation proved to be a difficult task in many developing countries due to political compulsions and development policies with a centralized approach [45]. On the other hand, the very nature of DE services delivery supports deregulation of the market.

## 5.4 Challenges of Decentralized Energy Services Delivery in Developing Countries

DE service delivery like any other system needs to overcome a number of challenges. The challenges from different perspectives are listed below.

**Technical perspective**: DE production systems supply energy just like any other centralized energy system, but constituent technologies need to match the local resources (such as energy sources and income) and end-user needs. Meeting these requirements demands customization of the technology. This customization of technology is a key challenge in DE services delivery from the technical perspective. It requires technical know-how and must consider end-user needs and resources besides ensuring reliability and affordability. In addition, the knowledge gap[3] existing in many developing countries increases the gravity of the challenge further.

**Economic or Financial perspective**: From end-user's perspective DE service delivery should be affordable, whereas for the service provider the delivery model must be economically viable. Accommodating both the end-user's and service provider's intentions introduce complexity into DE services delivery in many developing countries. This can be attributed to low income levels of typical end-users and the high production and delivery cost of DE services in general.

**Institutional perspective**: Small and Medium sized Enterprises (SMEs) are key players for delivering DE services due to the dispersed nature of the market. The main challenges in the case of SMEs in developing countries are lack of awareness about business opportunities and high investment costs. In addition, the current market models of SMEs are still evolving and are yet to attract external investments. DE service delivery requires knowledge ranging from the energy policy framework to

[3]The World Bank development report (1999), distinguishes two types of knowledge: knowledge about attributes leading to information problems and knowledge about technology (i.e. know-how), including knowledge gaps. Typically, developing countries have less of this know-how than industrial countries, and the poor have less than the non-poor. We call these unequal distributions across and within countries knowledge gaps.

auditing end-user needs. SMEs in many developing countries are not able to attract experts to fill the knowledge gap.

**Market perspective**: The exiting market conditions of energy in many developing countries can be characterized by subsidies, distorted prices and market regulation. In this scenario centralized energy service delivery benefits more than DE service delivery owing to economic and operational constraints. These conditions discourage market participation in DE services delivery.

DE services delivery have the theoretical potential to satisfy basic energy needs in developing countries especially in rural areas and can supplement centralized energy service delivery in urban areas. This approach have the capacity to stimulate the RET market and can promotes sustainable development in developing countries. The next chapter explains the importance of DE services delivery in an Indian context and different DE service delivery models at the institutional level in India.

# 6 Decentralized Energy Services Delivery in India

This part of the study is an attempt to understand DE service delivery models in developing countries from an Indian context. First, it is important to understand the energy scenario in India to understand the importance of DE services in the country. The second section explains about justification for considering India as a reference case. Third section concentrates on different DE service delivery models at an institutional level in India.

## 6.1 Energy Scenario in India

India is a developing country in south Asia. The Indian energy sector, like its economy, is at a crossroads: from a contrasting juxtaposition of formal and informal activities, the prevalence of low quality technologies alongside high tech activities, the wide disparity in the lifestyles of the rich and the poor and a distinct rural and urban divergence, the country aspires to leap forward to become a global economic powerhouse with low poverty [46]. The Indian energy sector can be characterized by the following characteristics.

**Fossil fuel dominant system**: The modern energy service system is dominate by fossil fuels in India and is centralized in nature. Among the fossil fuels, coal dominates over other energy sources like natural gas. In 2005, coal accounted for 55% of the total energy supply. Collectively, fossil fuels accounted for 72% of primary energy needs in 2005. [47]. This scenario is unsustainable in the future.

**Energy subsidies**: The energy sector is subject to public service obligation in India and influenced by political compulsions. Accordingly, the government plays an important role in the energy services delivery chain. This has resulted in energy subsidies to certain end-users. In 2005, fiscal spending for energy subsidies accounted for 20 billion USD [2].

**Rural-Urban divide**: The pattern of energy consumption varies widely between rural and urban areas. Based on the 2001 census, 90% of rural households depend on traditional energy services. On the other hand in urban areas, the dependency is less than 30%. The rural-urban disparity can also be observed in the case of electricity. About 43.5% of rural households have access to electricity. In contrast, about 87.6% of the urban households use electricity. [47]. Further, energy supply reliability is low in rural areas when compared with urban areas. This can be attributed to energy rationing to balance supply and demand.

**Energy access**: The Indian energy sector is facing significant challenges to provide energy access to rural areas (last mile). End-users need to have a regular income to participate in th modern energy services delivery chain. However, the poor normally lack a regular income. In such a scenario, modern energy services have to compete with traditional energy services. Further, operational and technical challenges need to be addressed to extend centralized energy services to dispersed locations. 24,500 villages out of 112,401 non-electrified villages are classified in the category of *remote villages*. A conventional grid extension is not possible in the near future in these villages [48]. The case of Deepam scheme in Andhrapradesh demonstrates the challenges in delivering modern energy services to improve energy access in rural areas [49].

**Energy shortages**: Energy policies in India have resulted in inadequate investments in the energy service delivery infrastructure. As a consequence, the country is facing chronic shortages of modern energy sources. In the case of electricity, the shortage is around 8% of the total demand [33]. Further, the enduring dependency on traditional energy services is causing a shortage of non-commercial energy sources in the proximity of end-users. Rural households in India spend from two to seven hours a day for collecting non-commercial energy sources [20].

**Inefficient energy equipment**: The efficiency of energy appliances is relatively low in India. This can be observed both at industrial and household levels. For example, the cement industry in India uses 95 kWh of electricity to produce one ton of cement, while the world's best practices use 77 kWh [50]. The energy saving potential varies from 12 to 60% depending on utilization type. However, significant economic and technical challenges need to be addressed in order to realize this potential. [25]

## 6.2 Justification for Considering India as a Case Study

Clearly, the energy scenario in India is in compliance with the energy scenario of developing countries discussed in the third chapter of this study. At the same time, India exhibits the typical characteristics of developing country from a social and economic perspective as shown in Table 6.1.

| **Parameter** | **Performance** | **Remark** |
|---|---|---|
| Literacy | 66% | Ranks 149 based on UNDP 2009 report |
| HDI | 0.519 | Ranks 119 based on UNDP 2010 report |
| Percapita income | $ 1030 | Ranks 139 based in The World Bank report, 2009 |
| Percapita energy consumption | 500 kgoe | It is one fourth of average global consumption based on Indian Environmental ministry statistics |
| Purchase power parity | $ 3275 | Ranks 112 based on The World Bank 2009 report |

Table 6.1: Social and economic characteristics of India at the global level

## 6.3 Decentralized Energy Services Delivery in India

Energy poverty is one of the most serious problems in India. The importance of decentralized energy services delivery to decrease the energy poverty was recognized in the early 1980s. The National Programme on Improved Chulhas (NPIC) was launched in 1983 to promote clean and efficient cooking practices to increase the fuel efficiency of traditional stoves and to reduce indoor air pollution. It was managed by the central governmental bureaucracy with the assistance of numerous state and district agencies [51]. Another programme, the National Project on Biogas Development (NPBD) was launched during 1981-82 to promote biogas use for cooking and lighting services in rural areas. The other objective of the programme was to reduce the drudgery of women. [52]. Central government with the assistance of state agencies administrated the NPBD programme. Nodal agencies at district level implemented the programme at end user level. The financial assistance from central government was the driving force behind both programmes. Decentralized energy services are delivered in three ways at an institutional level in India. They are public development agencies (PDAs), donor agencies and the market. The following section explains in detail about these three institutional delivery models.

### 6.3.1 Decentralized Energy Services Delivery by Public Development Agencies

Since the early 1980s, PDAs have been actively delivering DE services. Usually, The DE services are delivered with the assistance of other institutional stakeholders in the government, i.e. a top-down approach is used in this model. The energy transformation system (technology) is often *subsidized* to achieve the objectives of DE service delivery. For example, a minimum of 50% subsidy was offered to the end-user in the NPIC programme [51]. The presence of a subsidy leads to a complex institutional delivery structure to accomplish accountability. The institutional structure (Figure 6.1) of the NPIC implementation illustrates this complexity [53]. The primary drawback of this approach is the presence of multiple levels of government bureaucracy. It introduces bottlenecks during the service delivery process. In addition, the subsidy discourages technology or service providers to accommodate end-user needs and resources. The NPIC programme demonstrates the effect of subsidies. Producers of cooking stoves were motivated more by subsides than delivering DE services to the consumers. As a result stove producers did not consider end-user needs and resources. This course limited the success of the NPIC at the end-user level. [54]. Often, DE service delivery in this model is intended to demonstrate the technology to initiate *market-pull*. However, the evaluation studies of the NPIC and NPBD programmes suggests that the possibility of achieving market-pull is limited [[51], [52]]. In this thesis, to understand DE service delivery by PDAs, the "LED Village Campaign" in India is taken as a reference.

In the "LED village Campaign" an entire electrified village comprising of 200 to 250 households were provided with light emitting diode (LED) lamps. 3 to 4 light points of each household are considered for replacement. The scheme also includes replaces the existing street lamp luminaries of the village with LED Lamps. [55]. The objective of the project is to demonstrate LED lamp technology and to proliferate the information about their energy efficiency.

The Bureau of Energy Efficiency (BEE) is a central government organization working under Ministry of Power. The BEE is the ESP of the project. The BEE initiated DE service delivery with the assistance of State Designated Agencies (SDAs). Local implementation agencies have been implementing the project in one village of the respective state on behalf of the SDAs. The BEE has provided financial support to the tune of INR 1.5 million. Pagidipalli village in the state of Andhra Pradesh was

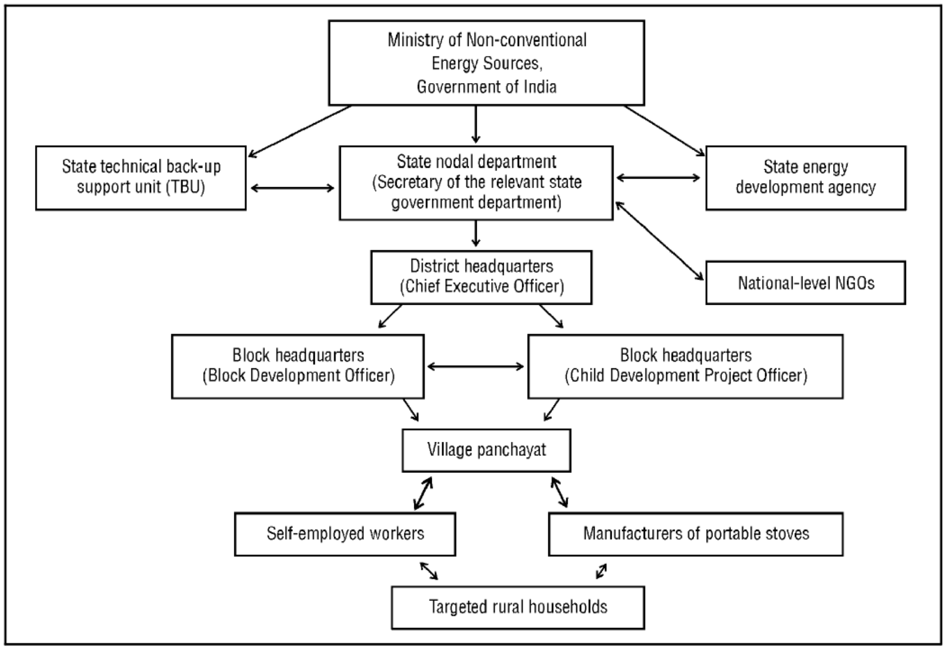


Figure 6.1: Institutional Structure of NPIC [53]

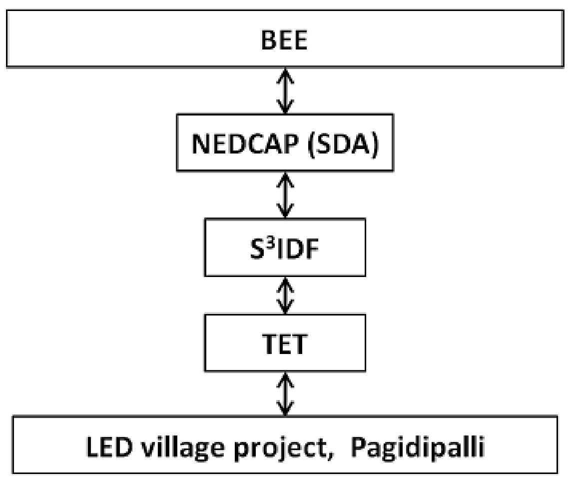


Figure 6.2: Institutional Structure of LED Village Campaign

considered for understanding DE service delivery by PDA in this study. The project was under progress during the field visit by the author. The Non-conventional Energy Development Corporation of Andhra Pradesh Limited (NEDCAP) a SDA of the BEE was responsible at state level for the project. NEDCAP appointed the Small Scale Sustainable Infrastructure Development Fund ($S^3IDF$) for selecting the implementation agency to implement the project in Pagidipalli. The $S^3IDF$ selected Thrive Energy Technologies Private Ltd (TET) to execute the project in

Pagidipalli. TET installed solar LED street lamps and distributed two LED lamps to each household in the village. TET replaces LED lamps given to the households in the case of failure and currently maintains street lights during their visit to the village every month. The institutional delivery structure of the LED village campaign is shown in Figure 6.2.

### 6.3.2 Decentralized Energy Services Delivery by Donor Agencies

Many non governmental organizations (NGOs) or donor agencies are delivering DE services in India. The sustainability of this model depends on continuation of the monetary assistance. However, this delivery model capacity and reliability are limited from an institutional perspective. This can be attributed to the external dependence of the energy delivery model. Danapur village in Patna district of Bihar is considered in order to understand DE service delivery by donor agencies. Before May 2010, villagers of Danapur had no access to energy services like lighting and clean water. Kotak Uja Private limited started providing energy services to the villages through a decentralized solar power station as a part of their corporate social responsibility programme.

Kotak Urja set up a solar power station as part of their solar village electrification programme in Danapur. The energy services, which are being provided to the villagers are indoor and outdoor lighting besides clean water. The company appointed local resident and trained him to deliver energy services to villagers. Solar lanterns and a battery are charged during day time. In the evening, the energy service facilitator (local resident appointed by the company) delivers solar lanterns to villagers and collects them the next morning. Battery power is used to purify water. In Danapur, all energy services are provided for free to the villagers. A monthly salary is paid to the energy service facilitator by the donor to ensure delivery of the energy services.

### 6.3.3 Decentralized Energy Service Delivery by Market

Historically, the market had a negative perception about DE services delivery in India due to the active participation of PDAs and donor agencies. The situation has changed with the arrival of new entrepreneurs, who have recognized the potential of DE services delivery from a business perspective. With their initiation, DE services delivery in India has evolved over past 15 years with the assistance of local actors in the delivery process. These local actors include Micro Finance Institutions (MFIs), donor agencies, and other development agencies. The service delivery process of Selco Solar Pvt. Ltd (SELCO) and Husk Power Systems (HPS) are observed during the field visit by the author to understand DE service delivery from a market perspective.

DE services delivery through the market takes two forms at the end-user level. They are end-user ownership model and pay for the service model. The end-user ownership model is used in the areas with low population density. Often, end-users in low population dense areas continue to depend on traditional energy services. This can be attributed to limited access to alternatives or insufficient knowledge of advantages of modern energy services. ESP initiates DE service delivery through marketing. The marketing process introduces the alternatives to the end-user. In addition, the importance of modern and efficient energy services are communicated to the end-user. Further, information about end-user needs and resources are collected for auditing for energy service production. The ESP seeks the assistance of local MFIs or cooperative societies or local NGOs, if the end-user's financial capacity is limited. This process creates a business opportunity to the financial institutions. In addition, it facilitates the necessary financial capacity for the end-user. The ESP starts production of the DE service system in the end user's proximity. The ESP creates a business opportunity for technology providers in the production process of DE service delivery. In addition, the ESP transfers essential information to the end-users for later maintenance of the energy service system. It reduces ESPs throughput effort in later stages. To summarize, the ESP customizes energy services delivery to accommodate end user needs and resources and creates value for other stakeholders in the process.

The ESP owns the DE service system in the case of the pay for service model. Usually, this delivery model is attractive in populated areas. In the pay for service model, the marketing process involves convincing a sufficient number of end-users to participate in DE services delivery. It is important to achieve economies of scale. Production and maintenance processes are difficult in this type of DE service delivery. This can be attributed to the high capital cost of DE service system.

DE service delivery is essential to achieve socio-economic development in developing countries. PDAs deliver DE services to demonstrate new technologies besides the development perspective. Donor agencies deliver DE services to achieving social development. Business proposition motivates the market to deliver DE services. To conclude, DE service delivery needs to be promoted as a business opportunity to improve energy access in developing countries.

# 7 Process Mapping of Decentralized Energy Services Delivery in Developing Countries

The importance of decentralized energy (DE) services delivery is recognized in developing countries. Institutionally, DE service delivery is gaining momentum in developing countries. DE services delivery requires institutional analysis for strengthening and promoting different DE service delivery models besides the existing research trends discussed in the previous chapter. This chapter is an attempt to carry out institutional analysis of those models. In this study for institutional analysis, the process mapping technique is used which was discussed in detail in the second chapter of this thesis. For process mapping, data was collected in India during the field trip by the author besides the information available on the Internet which include reports by different development agencies. The first part of this chapter explains the importance of institutional analysis of DE services delivery models following their service delivery process maps.

## 7.1 Institutional Analysis

Any manageable system is limited in achieving more of its goal by a very small number of constraints, and that there is always at least one constraint based on theory of constraints proposed by Dr. Eliyahu M. Goldratt in his 1984 book titled “The Goal”. Based on this theory of constraints, the first step to identify the constraints is to understand the process inside the organization along with supportive acts performed by other stakeholders or entities and analyzing those activities. This approach is known as institutional analysis.

Institutional analysis is focused on the systematic study of collective behavior of the stakeholders involved in an institutional environment. It involves analyzing a broad range of responsibilities and actions of different stakeholders or entities in the organization at different levels. Many features of institutions are so normal that the stakeholders or entities involved may not even be aware of them or consider them worth analyzing. However, improving the performance of the institution requires diagnostic activity which provides comprehensive information about resource consumption, responsibilities of different entities or stakeholders and other internal and external activities in the process of achieving its strategic intentions. Process mapping is one such diagnostic tool for institutional analysis. The methodology of DE service process mapping was explained in the third chapter of this thesis.

## 7.2 Process Mapping of Decentralized Energy Service Delivery by Public Development Agencies

The governance process mapping of DE services delivery by PDA is shown in Figure 7.1. The PDA is the ESP in this delivery model. Often, this routine is used either for technology demonstration or social development. The PDA with the assistance of nodal and implementation agencies deliver DE services to the end-user. Nodal and implementation agencies act as carriers between ESP and the end user. Based on specific intentions of the PDA in DE services delivery, a transactional environment exists between other stakeholders in the process. Implementation agencies play a vital role in this routine due to their relative proximity to the end-user. The stakeholder's responsibilities or roles are listed below

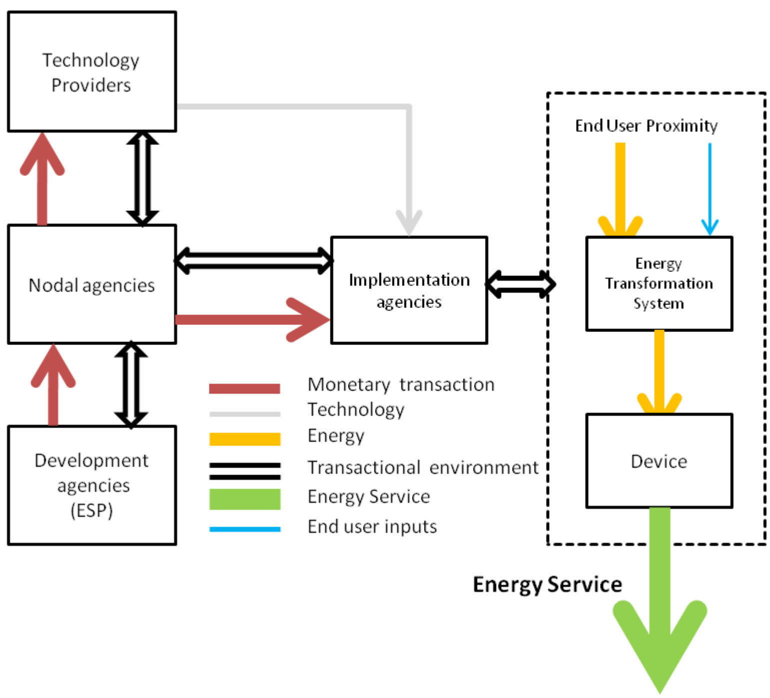


Figure 7.1: Process map of governance: DE service delivery by PDAs

The **Public development agency** tabulates specific objective of DE services delivery as ESP. Often, capital support is provided by the PDA to nodal agencies to accomplish the objective with the assistance of other stakeholders. The **Nodal agency** bridges the institutional gap between ESP and implementation agency. In addition, it coordinates the interaction between the technology provider and implementation agency. Further, it administers DE services delivery process on behalf of

ESP. The **technology provider** renders essential information to the implementation agencies besides supplying technology. The **implementation agencies** play a vital role in this delivery model due to their relative proximity to the end-user, acting as field agents. Further, they interact in a transactional environment with the nodal agency and the end-user and receives financial support from the nodal agencies. The **end-user** role is limited in the case of delivery model due to the top-down approach.

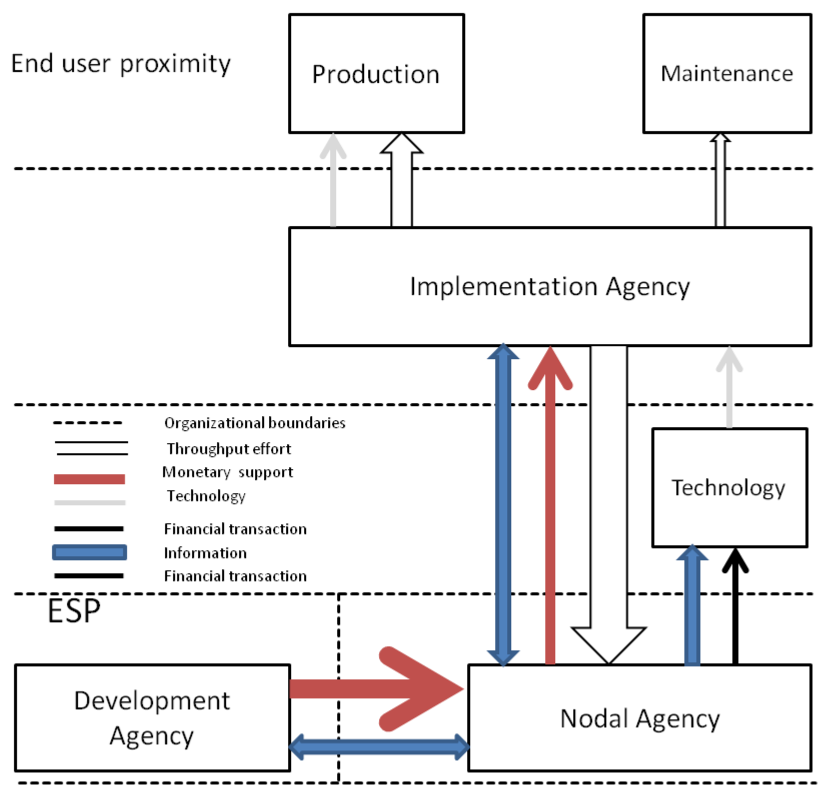


Figure 7.2: Process map of service delivery process: DE service delivey by PDAs

The service delivery process mapping of DE services delivery by PDAs is shown in Figure 7.2. The PDAs monetary support mainly contributes to the success of DE services delivery. As shown in the figure, the implementation agencies play an important role in this routine. The implementation agencies focus more on the monetary support than delivering energy services delivery to the end-user. Accountability of this model is relatively low due to the top-down approach taken. Further, the probability of scaling and replicating this delivery model is minimal due to increasing fiscal deficits in developing countries in general as shown in Figure 4.7. Production of DE services delivery however is easier, although service system maintenance is a difficult task as this process has no additional value to the implementation agency. The end-user energy needs and resources receive very little importance in this model due to the top-down approach taken.

## 7.3 Process Map of Decentralized Energy Service Delivery by Donor Agencies

Development is the objective of donor agencies in the case of DE services delivery. The governance process mapping of this delivery model is shown in Figure 7.3. The donor agencies deliver energy services in this routine with the assistance of the implementation agencies. The donor agencies provide monetary support to the implementation agencies. Further, the donor agencies require external support to continue their mission of delivering DE services in this model. The implementation agencies also play a vital role in this model. Different Stakeholder's responsibilities and roles are explained below.

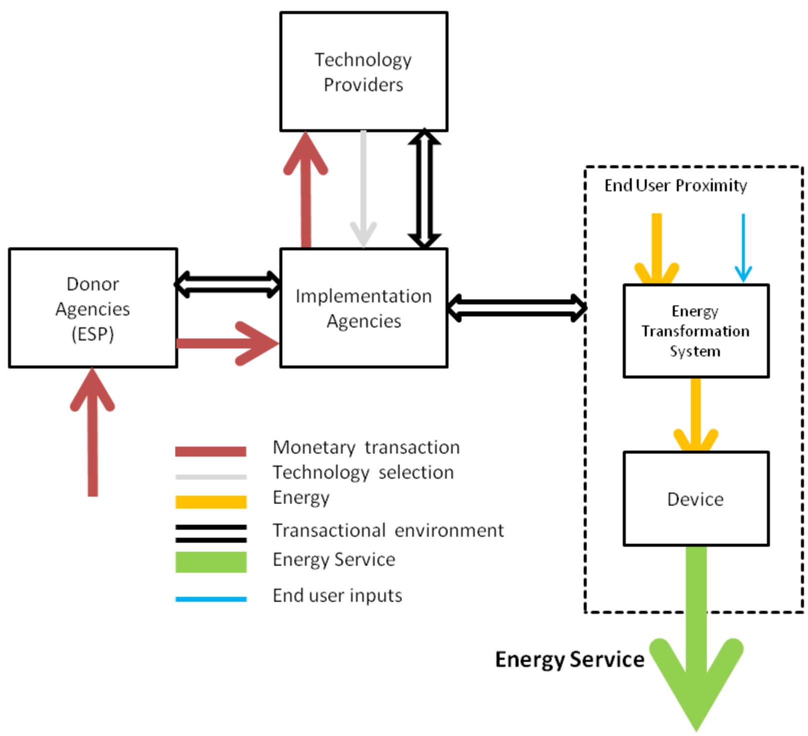


Figure 7.3: Process map of governance: DE service delivery by donor agencies

The **donor agencies**, who often operate from abroad, provide monetary support to the implementation agencies. This limits their role in DE service delivery. The **implementation agency** has an important role to play in DE services delivery in this model. It enforces the intentions of donor agencies like in earlier delivery model. Further, it interacts with the donor agency in a transactional environment. **Technology providers** play a similar role in this delivery as in the case of the PDA. The **end user** role is limited in the case of DE services delivery by the donor agencies because of the top-down approach taken.

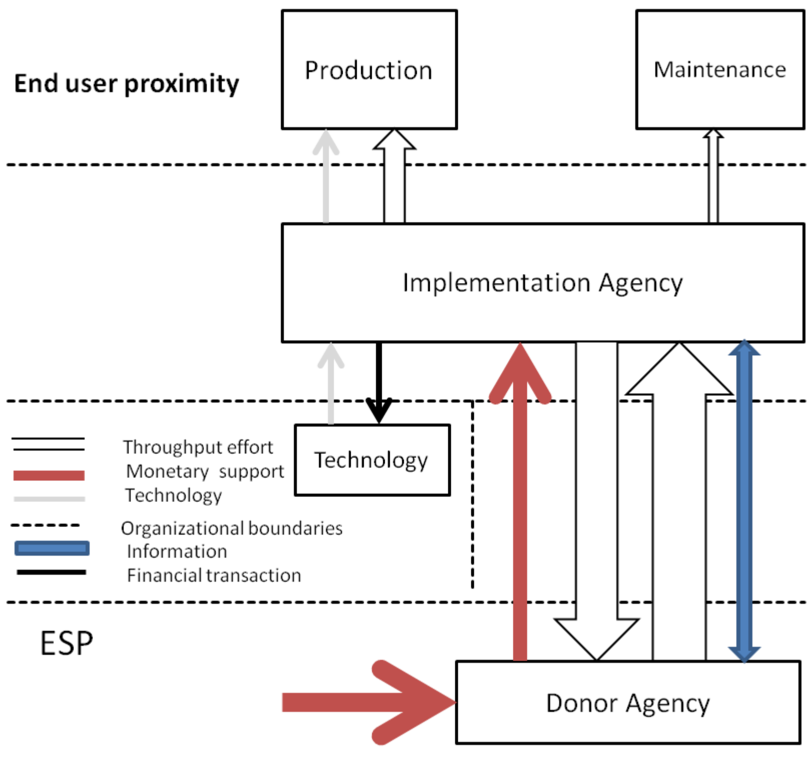


Figure 7.4: Process map of service delivery process: DE service delivey by donor agencies

The service delivery process mapping of DE services delivery by donor agencies is shown in Figure 7.4. The donor agency's monetary support is the tangible value from the implementation agency's perspective. Therefore, throughput effort is maximum in the process of receiving monetary support. The accountability of this model varies from moderate to high due to the effort of the donor agencies. The probability of scaling and replicating DE service delivery by the donor agencies is very minimal due to the external dependence for monetary support. Production of energy service is a easy process. Maintenance process, however, creates no additional value for the implementation agency. Therefore, DE service systems maintenance is difficult in this delivery model. The end-user needs are accommodated to limited extent in this model due to the development perspective of the donor agencies.

## 7.4 Process Map of Decentralized Energy Service Delivery by Market

The market is in the initial stages of evolution in the case of DE services delivery in developing countries. Unlike other models, the market approach is bottom-up in nature. End-user ownership and pay for service constitutes two different delivery models in the case of the market. ESP in the market model acts as a coordinator between other stakeholder in the delivery process and creates value for the stakeholders in the process of delivering energy services to the end user. In this delivery model the ESP bridges the gap between technology providers and end users. The development agencies support ESP's activities. For example, the UNFCCC supports ESPs through clean development mechanism (CDM) programme. The governance process mapping of DE services delivery by the market are shown in Figure 7.5 and Figure 7.6. Major difference between two delivery models is the existence of financial institutions in the case of end user ownership. Financial institutions provide financial support to the end-user to address the high up-front cost of service system. Different stakeholders and their roles and responsibilities are discussed below.

The **Development agencies** tabulate supporting policies for improving energy services by offering monetary support to ESPs. Examples of development agencies are respective governments, donor agencies and institutions like UNFCC and the 'World Bank. **Nodal agencies** acts as coordinator between the ESP and development agencies in the process of offering external monetary support. The **energy service provider** (ESP) role is critical in DE services delivery. ESP offers wide range of services to other stakeholders in the delivery process. In the case of end-user ownership, ESP persuades financial institutions to finance DE service system on behalf of the end users. This process creates business value for financial institutions and facilitates the affordability to the end-user. Likewise, market value is created for technology providers as the ESP bridges the gap between technology and the end user. The main responsibility of ESP in DE services delivery is to convince the end users to change their energy usage patterns. This process is difficult due to the

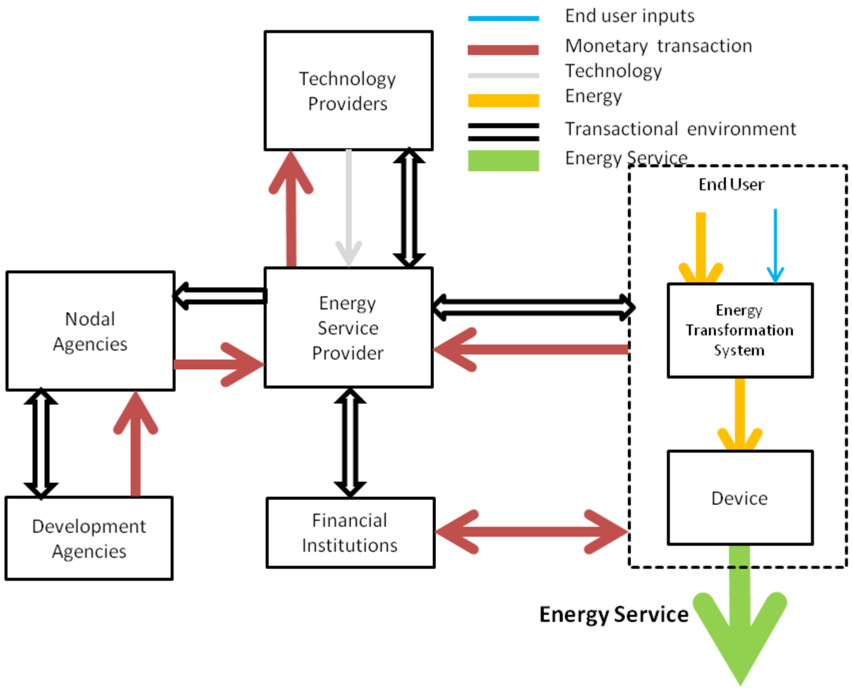


Figure 7.5: Process map of governance: DE service delivery by market (end user ownership)

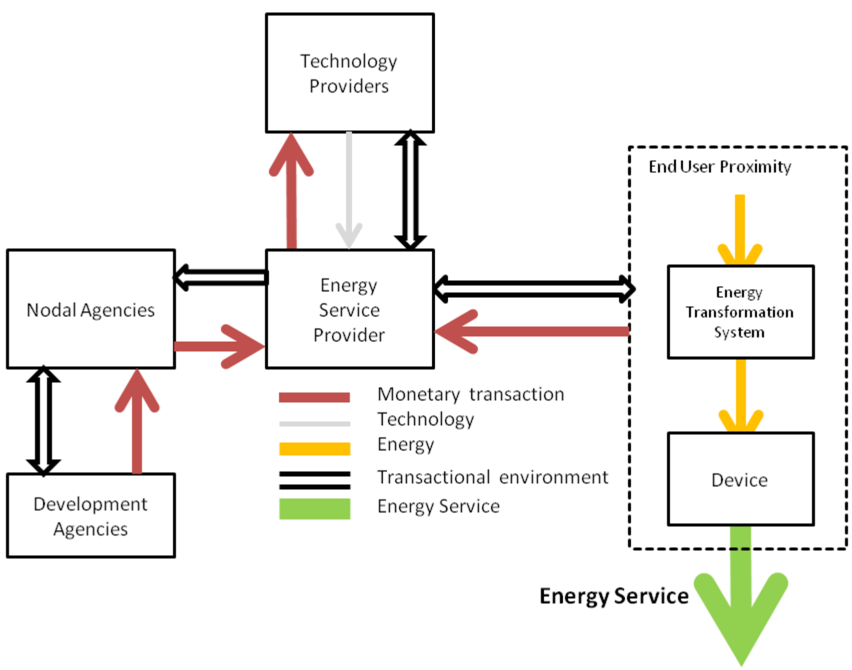


Figure 7.6: Process map of governance: DE service delivery by market (pay for service)

availability of substitutes. In addition, the ESP need to ensure the reliability of DE services to end-users. The end-user needs and resources are accommodated in this delivery model.

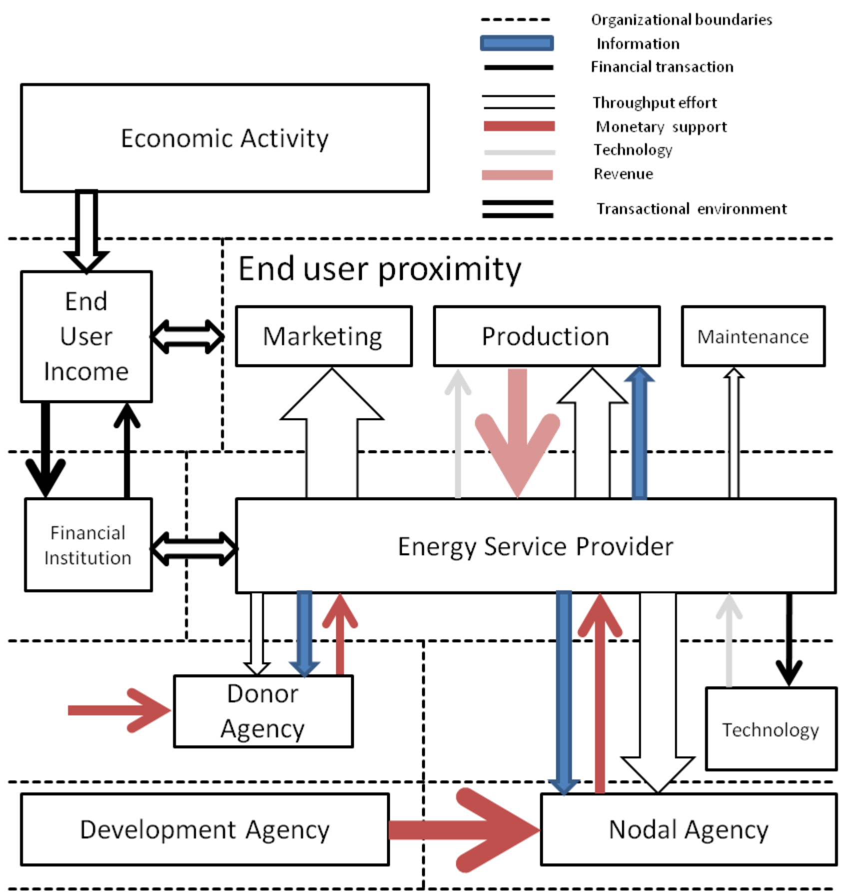


Figure 7.7: Process map of service delivery process: DE service delivey by market (end user ownership model)

The **technology providers** render support to the ESP for installation and maintenance of DE service systems and are actively involved in DE services delivery. This activeness can be attributed to energy service providers performance translates into the technology providers market share unlike earlier approaches (PDA and donor). **Financial institutions** play an important role in remote rural areas. Energy services are offered through end-user ownership DE service systems in those areas. Generally, weak economic activities in those areas effect the affordability of end-users to own DE service systems. Financial institutions provide assistance to address these affordability issues. MFIs and cooperative societies are typical examples of financial institutions in DE services delivery. The **end-user** is a key stakeholder in DE services delivery by market as his participation creates value for other stakeholders in the process with limited liability. For ESPs, end user participation creates value (revenue), whereas for technology providers the value is market opportunity. In the case of development agencies the value is sustainable development.

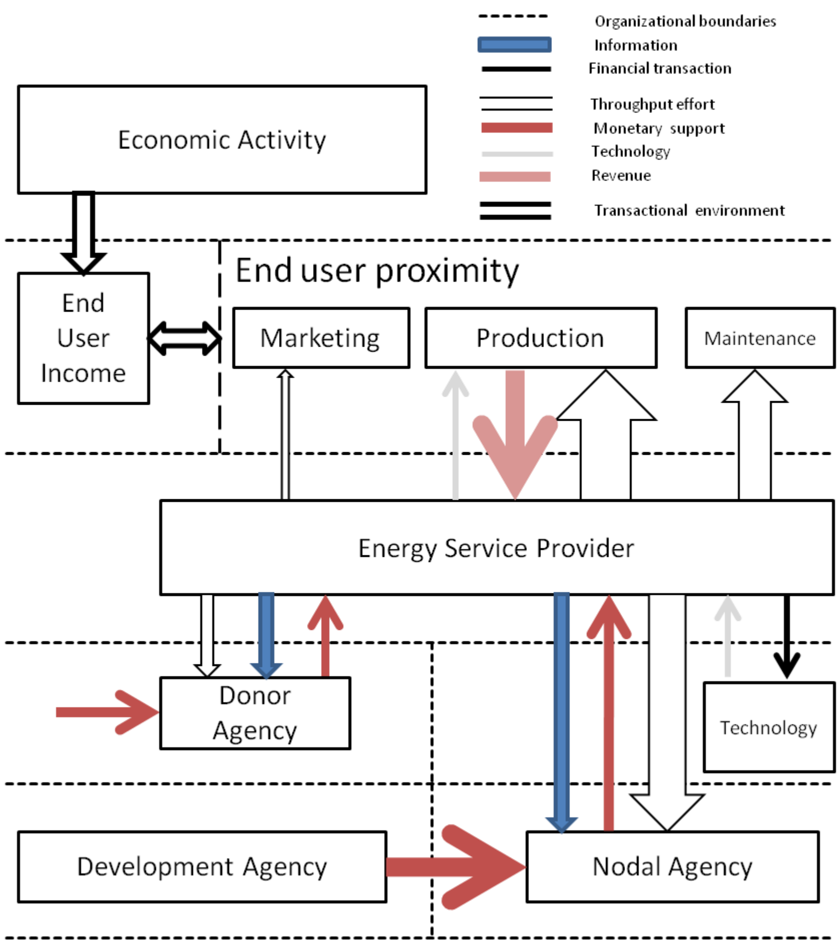


Figure 7.8: Process map of service delivery process: DE service delivey by market (pay for service model)

The service delivery process mapping of DE services delivery by markets in the case of end ownership is shown in Figure 7.7. The service provider plays a vital role besides economic activity as shown in the figure. The service provider ensures the delivery of energy services to the end-user. Economic activity enables the end-user to participate in DE services delivery by the market. Value is created during the production process of DE services for the service provider. Development agencies support the service provider through monetary incentives. However, the relative throughput effort is more in the case of public development agencies compared to donor agencies. Often, the service provider initiates the marketing process of DE services in developing countries. The throughput effort is maximum during this process. This level of effort can be attributed to the knowledge-gap of the end-user. During the production process, the ESP provides essential information to the end user to reduce his throughput effort during the maintenance process. Accountability is high in this model due to market oriented approach. The market approach customizes DE service delivery based on the economic activity of the end-user. Further, it accommodates end-user needs and resources. unlike earlier approaches, DE service delivery links income generation activity and energy service to provide additional cash flow to the end user. The additional cash flow enables end users affordability and improves their quality of life.

The service delivery process map of DE services delivery by markets in the case of pay for service is shown in Figure 7.8. The major advantage with this approach is the relative degree of economies of scale. The affordability of the end-user is high in this model. Economic liability is high for the ESP compared to the end-user ownership model. Throughput effort is maximum during the production of DE services followed by the maintenance activities in this delivery model. The Market approach demonstrates sustainability. Institutional analysis of different DE service delivery models in developing countries is tabulated in Table 7.1.

| characteristic | Energy Service Delivery Model | | | |
|---|---|---|---|---|
| | PDA | Donor | Market | |
| | | | End User Ownership | Pay for Service |
| Replication | Low | Low | Moderate to High | High |
| Scalability | Low | Low | Moderate to High | High |
| Accountability | Low | Moderate to High | Low to moderate | High |
| Sustainability | Low | Low | Moderate to High | Moderate to high |
| Marketing | Not Applicable | Not Applicable | Difficult | Easy to Moderate |
| Production | Not Applicable | Not Applicable | Difficult | Easy to Moderate |
| Maintenance | Moderate to Difficult | Moderate to Difficult | Easy to Moderate | Moderate to Difficult |

Table 7.1: Institutional analysis of different decentralized energy service delivery models in developing countries

# 8 Walkthrough Audit of Decentralized Energy Services Delivery by the Market in India

The market has the capacity to improve energy services delivery in developing countries in a decentralized manner. In this approach, the service provider offers DE services in a professional manner to the end-users by customization. Therefore, understanding end-user perspective is important to improve the service performance from the standpoint of other stakeholders in the process. This can be achieved by a walkthrough audit [11]. In walkthrough audit, the service experience of the end user is systematically evaluated. It provides enough information from the end-user's perspective for promoting decentralized energy services delivery in developing countries. In this study, a walkthough audit was performed in India to understand service experience of the end user. The results are tabulated in Table 8.1.

A total of 32 correspondents, who are end-users of DE services in India, are interviewed to analyze the service experience. 22 of them are using pay for service DE services and the rest own a DE service system. It is clear from the survey that end users preferred DE service for energy needs. The ESP informed them about the availability of alternative energy services through marketing. Therefore, **market** initiation is required to promote DE service in developing countries. Many of the end-users are unaware of the environmental sustainability of the DE services, which demonstrates present clean energy initiative is not the right way of promoting energy in developing countries. In the case of end-user ownership, end-users felt presence of ESP made access to finance easier to obtain as ESP approached the financial institutions on their behalf. Overall, end-users are satisfied with the performance of both the ESP and energy service system.

Table 8.1: Service evaluation survey

| Question | | % in range |
|---|---|---|
| **Pre service** | | |
| Who initiated energy services marketing? | | |
| | Service provider | 93.75 |
| | End user | 6.25 |
| **During service** | | |
| How would you rate service provided by the ESP? | | |
| | Very satisfied | 31.25 |
| | Satisfied | 46.875 |
| | Mildly satisfied | 21.875 |
| | Not satisfied | 0 |
| **After service** | | |
| Is the energy service system used as a primary or auxiliary source? | | |
| | Main | 93.75 |
| | auxiliary | 6.25 |
| How reliable is energy service system? | | |
| | Very satisfied | 43.75 |
| | Satisfied | 43.75 |
| | Mildly satisfied | 12.5 |
| | Not satisfied | 0 |
| Why do you prefer decentralized energy services? | | |
| | Need | 96.875 |
| | Clean Energy | 3.125 |
| Are you aware of the environmental sustainability of the energy services? | | |
| | Yes | 25 |
| | No | 75 |
| Do you want to buy more energy from the service provider?* | | |
| | Yes | 55 |
| | No | 45 |

* Only the end users of pay for service model

# 9 Conclusion

The promotion of decentralized energy services delivery is essential to achieve sustainable socio-economic development in developing countries. The market approach demonstrates sustainability and scalability. Infusing renewable energy technologies to decentralized energy service systems can address global concerns about existing energy utilization practices in developing countries. In addition, it can provide the necessary market-pull for renewable energy technologies. Decentralized energy service delivery has the theoretical potential to supplement and strengthen the current centralized energy services delivery system in developing countries.

Existing market conditions need to be improved for promoting sustainable decentralized energy service delivery through the market. Improvement is essential in order to overcome competitive disadvantages introduced by the distorted energy prices of centralized energy service delivery.

At the macro level, the knowledge gap in the field of energy, is a major concern in developing countries. The gap is effecting small and medium enterprises, who are delivering or want to deliver energy services. Therefore, promotion of energy education and expertize is required to promote decentralized energy services delivery in developing countries. This reduces the throughput effort of the energy service provider in non-value added time in the service delivery. In addition, development agencies need to promote decentralized energy services delivery as an opportunity rather than a development perspective. The extent of bureaucracy levels need to minimized in order to benefit from institutional incentives. This requires further of decentralization of institutional hierarchy of development agencies.

From, the walkthrough audit it is evident that a bottom-up approach is required to promote decentralized energy services in developing countries. Energy service providers need to take initiation for promoting energy services due to the knowledge deficit of a typical end-user. Success can be achieved, if end user needs and resources are given importance during decentralized energy services delivery. The capacity of the end-user to participate in decentralized energy services delivery depends on economic activities in his proximity. Linking energy services delivery to income generation is essential in the case of economically deprived end-users.

To conclude, the energy service provider is an important player in delivering decentralized energy service. He bridges the conceptual gap existing between end-users and other stakeholders in the delivery process (technology providers and development agencies). Constructive and effective support from other stakeholders is required to realize the full potential of decentralized energy services in developing countries.

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