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Commercialisation of Sustainable Energy Technologies

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Abstract

Commercialization efforts to diffuse sustainable energy technologies (SETs) need to be sustainable in terms of replication, spread and longevity, and should promote goal of sustainable development. Limited success of diffusion through government driven pathways illustrates the need for market-based approaches to SET commercialization. This paper presents a detailed treatment of the pre-requisites for adopting a private sector driven "business model" approach for successful diffusion of SETs. This is expected to integrate the processes of market transformation and entrepreneurship development with innovative regulatory, marketing, financing, incentive and intermediary mechanisms. Further, it envisages a public-private partnership driven-mechanism as a framework for diffusion leading to technology commercialization.

Key words: Commercialisation, Energy, Financing, Technology, Sustainable

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1. Introduction

The role of technology in the sustainable economic development of a country is crucial. In general, technology is viewed as a mechanism, which transforms the natural resources into goods and services useful for the survival of human life. The technologies are expected to facilitate improvement in living standards, promotion of efficient use of resources, adaptation to local conditions and needs, and integration with other existing technologies. In short, the technologies should meet both the livelihood and lifestyle needs of people in a sustainable manner. In the era of liberalized and interdependent global economy, technology has emerged as the driving force behind: structure of domestic production, advantage in market competition, opportunities for cross border trade, and growth in standards of living of people (ADB, 1995). However, this technology-related development has increased the demand for energy and associated emissions of green house gases (GHGs). The concern is more serious with developing countries because they are adopting various policies for speeding up the process of economic development in attempting to catch up with developed countries. As recognition of increasing concern about environmental impacts, the international community is again looking towards technologies to provide a solace to this problem. It is thus not surprising that a frequently expressed view on global climate change has been "If the introduction of technologies created the problem, other new technologies will help in solving it" (IPCC, 2000).

Sustainability issues with respect to technology diffusion can be two pronged. First, the technology diffusion process itself needs to be sustainable in terms of replication, spread and longevity. Secondly, the technologies thus diffused should promote sustainable development in the form of meeting the needs of all and at the same time causing minimum damages to the environment. This paper takes the case of sustainable energy technologies (SETs) to analyze the above issues. Broadly, the SETs can be viewed as a portfolio of technologies, which are: Expected to use renewable energy resources for producing modern energy carriers; Utilize these energy carriers efficiently; Cost effective; High quality and reliable; Appropriately sized to meet the needs of inaccessible people; and Minimum environmental damages. With these attributes, the SETs can be expected to contribute in satisfying the goal of sustainable development by providing access to better quality energy to the people who are deprived of it and to uplift their living standards, and contributing significantly in mitigating climate change impacts. This transition will depend not only on the presence of alternative technology but also on its diffusion, its dissemination, and application in society at large. In other words, good technological options should not just lie on the shelf collecting dust. It has been assessed that the energy supply/savings potential that could be created through SETs is very large. However, this potential will remain on paper or remain just an estimated number unless there is large-scale diffusion of these technologies. An additional benefit of realizing this potential is the positive impact on the environment. Significant environmental benefits are often associated with the rapid diffusion of modern energy technologies. The key question is how to achieve such a large-scale diffusion.

SETs need to attain the status of commercialized technologies in order to make any significant impact on energy systems. Commercialization is here defined as the creation of self-sustaining markets that thrive without subsidies in a level playing field with other technologies. Without commercial status, SETs will neither gain the customer’s confidence, nor benefit from the dynamism and innovation of the private economy. To make them commercially viable, a well designed integrated diffusion process is essential involving multiple stakeholders with a proper enabling environment through government policies, transformed markets, and information services. The impetus given by such a diffusion process can lead to successful commercialization of SETs.

SET diffusion at present is mostly dependent on government driven pathways, such as active involvement in R&D activities, demonstration projects financed by either local or international funding agencies, and government sponsored programmes to determine the resource availability. Experience with such government driven pathways or development assistance for sustainable energy projects in developing countries over the past three decades illustrates the importance of sustainable market based approaches to technology commercialization.

In light of this, a private sector driven “business model” approach is presented here for a successful diffusion of SETs. However, governments, NGOs, international agencies and community groups also need to participate in this process but their role is limited as enablers, supporters, facilitators and guarantors. This approach is expected to integrate the processes of market transformation, entrepreneurship development, innovative marketing mechanism, innovative incentive mechanisms, innovative monitoring and performance contracting mechanism as a pathway to successful technology diffusion. Further, it envisages a public-private partnership driven mechanism as a possible framework for diffusion. We believe that such an approach is the most appropriate one for commercializing SETs.

2. Commercialisation of Technologies

2.1 Technology generation

The generation of technology involves the “innovation chain” which is the sequence of steps by which an idea or concept is converted into a product or process. This sequence of steps varies with the circumstances, but can often be schematically represented thus:

Idea/Concept → Relevant Basic Research → Applied Research → Development & Design → Engineering for Manufacturing → Marketing → Product/Services

The terms are defined as follows:

- *Relevant Basic Research* refers to the synthesis or assembly of understanding relevant to the technological objectives;
- *Applied Research* is the activity of demonstrating the technical feasibility or the synthesis of understanding leading to a new technology;
- *Development and Design* describes the activity of coming up with a version of the new product/service that can be 'commercialized' in the economy, that is, a product/service that meets performance, reliability and economic requirements;
- *Engineering for Manufacturing*, to the activity of demonstrating that the working technology can be manufactured at a price acceptable to the economy.

2.2 Technology Commercialisation

The 'commercialization' concept describes the process of developing an idea into a marketable product. Commercialization is the total process of moving a technology from the concept stage, to the production of a product and from there, to market acceptance and use. Innovation is distinguished in the literature on the study of Science and Technology from invention even though these two terms are used interchangeably in ordinary language. The term innovation is used to describe the process of transforming an idea or concept into a product/service. It includes much more than the term invention, which is usually restricted to the process of going from an idea or concept to a contrivance or prototype or design. In addition to invention, innovation involves the crucial process of commercializing the product or service in the economic activity of the country. The process of innovation can be represented as shown in the figure by the innovation chain, which is the chain of steps leading from an idea or concept to a product/service in the economy. The commercialization process involves a process to develop a technology from concept to commercially available device through various steps. The exact sequence of steps depends upon the sector – industry, agriculture, transport, education, health, communication, and so on. One possible sequence of steps in the innovation chain may be as follows (Reddy AKN, 1996):

Concept → Feasible Device → Working Device → Manufacturable Device → Commercially Disseminated Device

It is important to note that every pattern of technology is socially conditioned. Technology is a product of its times and context, and bears the stamp of its origins and nurture. It is in this sense that technology can be considered to resemble genetic material that carries the code of the society, which conceived and nurtured it and, given a favourable milieu, tries to replicate that society. Surely the reverse is equally true, namely that technologies profoundly shape societies, sometimes in unanticipated ways, while creating both positive and negative effects in the process.

Thus, technological commercilisation is based on ideas, the conversion of ideas into inventions (working devices/processes), the commercialization of inventions into innovations (commercially viable devices/processes), and finally, the widespread adoption and dissemination of innovations by users. For a successful commercilisation of a technology, the following steps are important.

(i) Identification of the potential adopters

(ii) Measuring the perceptions of relevant potential adopters

(iii) Designing and developing a user-friendly product

(iv) Informing the potential adopter of the product's user-friendliness

(v) Providing post-adoption support

For a successful commercialization of a technology the essential requirement is the creation of self-sustaining markets that thrive without any form of subsidy in a level playing field with other technologies. The term ‘commercialization’ could be replaced with ‘market formation’. Both terms denote a process, which makes technologies increasingly profitable over time and thus reduces the need for subsidies and other forms of support. Specifically, commercialization means letting private actors handle economic transactions such as developing and financing projects in accordance with basic rules established and enforced by the government. Table 1 provides information on various phases of technology commercilisation.

Table 1: Technology commercialization model

	Technical	Market	Business
Investigation Phase	Technology Concept Assessment	Market Needs Assessment	Venture Assessment
Development Phase			
Feasibility	Technology Feasibility	Market Study	Economic Feasibility
Planning	Engineering Prototype	Strategic Marketing	Business Plan
Introduction	Pre-Production Prototype	Market Validation	Business Start- Up
Commercial Phase			
Full Scale Production	Production	Sales and Distribution	Business Growth
Maturity	Production Support	Market Diversification	Business Maturity

Commercialization is an important benchmark for sustainability for the following reasons:

- It is causally and positively related to the benefits associated with clean technologies such as environmental gains and health improvements. The faster the commercialization process, the greater are these benefits;

- When full commercialization is achieved, the benefits associated with clean technologies can come at zero or negative cost to taxpayers. Once a technology is commercial, benefits continue to accrue without incurring cost to taxpayers;
- Consumers and firms who invest wisely in clean technologies also benefit from negative cost (profit).

The indicators that can be used to highlight different dimensions of commercialisation include: (1) the profitability of projects, (2) technology cost trends, (3) the share of private activity in the market, for example, the share of energy production/savings generated by the private sector or the amount of profit-driven private investment for energy efficiency improvements,[2] (4) business and support service development (eg. clusters), (5) the availability of commercial financing, (6) awareness and understanding of technologies and benefits among consumers and businesses, and (7) consumer and business demand. Taken together, these indicators can adequately represent the complex process of commercialisation (Nichols and Martinot, 2000).

Commercialization of SETs cannot be automatic because of the existence of barriers. The process can be smooth for those technologies, which are better off in terms of energy use efficiency (thermal) or in terms of initial cost, quality, reliability, and so on. Market forces sometimes ensure the spread of such technologies despite the existence of barriers. However, technologies, which aim at commercialization solely with the advantage of energy efficiency, may not succeed. A special impetus is needed to make this happen. SETs and environmentally sound technologies in general, face problems, which are not faced by other technologies. Environmental technologies face competition from equally competent, cost effective, and mature existing technologies. The need for these technologies arises more

[2] Related but less precise indicators are: (1) installed capacity run by the private sector and (2) number of private businesses operating in a particular market.

because of environmental and social concerns rather than business concerns. There is also resistance to change imposed by existing technological trajectories (Menanteau and Lefebvre, 2000).

Consider the example of Compact Fluorescent Lamps (CFLs), which are far superior in terms of luminous efficiency and working life to the incandescent lamp. Even so, the diffusion of this technology met — and is still meeting — with considerable resistance from an established technology which has benefited from a long learning process, considerable economies of scale in production, a wide distribution network, technological interrelatedness, increasing informational returns, and so on.

It is important to note that each technology occupies a different position in the process towards commercialization, and that this position can change over time. Some technologies commercialize faster than others. In general, one may say that the performance of environmentally sustainable technologies has not been stellar. At a time when the wheels of technological progress interlock more tightly with commerce and finance, many sustainable technologies lag behind other technologies in terms of commercialization, *despite* — or perhaps *because of* — long-standing efforts to promote them. Other technologies have experienced explosive market growth with less public support, while overcoming similar barriers that hold back environmental technologies (for example sceptical consumers, lack of sales infrastructure, lack of a regulatory framework, or unfavourable regulation). While technology sectors like the Internet, biotechnology, mobile telephony and others are growing in leaps and bounds, sustainable technologies live relatively quiet lives, ostensibly undisturbed by the hum and buzz in technology markets around them.

2.3 Limited Success of technology commercialisation

Clean energy technologies like renewable energy and energy efficiency had modest beginnings: limited commercial opportunities, interest, and funding. From the early 1970s onwards (especially after the first oil crisis of 1973), there have been steady streams of predictions that sometime in the 'not too distant' future, the market for clean energy would boom. Decades have passed since these predictions, and despite many efforts of governments, multilateral institutions, NGOs, and even a number of companies and investors, there has been no sustained take-off. The grip of conventional technologies on energy markets is still strong. Although some environmental technologies have become profitable in certain applications, and others are on the verge of being profitable, there has been no overwhelming influx of human and financial capital into the clean energy sector (IEA, 1997a, b, c, d, f, 1998b, 1999a, g, h, 2000). The revolution is still waiting to happen.[3]

It seems that without much greater private sector involvement and financing, governments and multilateral institutions cannot be effective at producing lasting technological innovation, technology diffusion, and technology transfer.[4] One may ask why governments, multilateral institutions, and other organizations had such a limited success in enabling environmentally sound technologies to be financed in a commercial setting. Drawing upon a quite considerable treasure of experience, we can distinguish two basic explanatory avenues. One could be described as 'lack of trying', whereas the other could be termed 'lack of ability':

- *Lack of trying* does not imply that there were no attempts to promote environmental technologies; it means that governments and multilateral institutions focused their attention on deploying technologies, rather than on commercialization as a policy objective. Clearly, not everybody has an interest in the commercialization of environmental technologies. While industries that focus on fossil fuels would be the

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[3] Some renewable energy technologies already achieve impressive growth rates: Hawken, Lovins, and Lovins (1999) cite figures that wind power is the fastest growing energy technology — even faster than energy efficiency technologies — with an annual growth rate of 26 percent, while solar PV has recorded growth of between 23 - 42 percent in the past few years. Based on Royal Dutch/Shell forecasts, renewables could supply up to half the world's energy by 2050.

[4] OECD 2000. The traditional model of technology transfer was a flow of equipment and know-how from industrial to developing countries. Reverse transfers as well as 'South-South' technological cooperation was neglected for a long time. In the sustainable energy sector, however, reverse transfers are becoming increasingly important, as many developing countries now have their own production of sustainable energy technologies.

primary losers, the commercialization of clean energy would also obviate the need for involvement of state and multilateral institutions.

- *Lack of ability* is also a plausible explanation for the failure to create private sector capacity and motivation. There have been many public-sector programmes to promote renewable energy and energy efficiency, but so far they have had limited impact in terms of bringing these technologies to market. Research and development, demonstrations, technical assistance, training programmes, institutional development, and subsidies may all play a role in commercialization. However, the effectiveness of these instruments can be questioned, since despite many programmes, most clean energy technologies are still not fully commercial.

While so far sustainable energy has been largely government financed, the private sector has increased its investment exposure in recent years. Fully financed projects by the private sector are still limited to niche markets, but even traditionally hostile oil companies have begun to develop and finance clean energy projects. Critics have pointed out that the share of environmental investments is still very low and that they serve mainly as vehicles for public relations. Others argue that oil companies are genuinely transforming to become energy companies, and that they are preparing themselves for a future where emissions markets could accelerate the commercial development of clean energy technologies. Still, if sustainable energy is to take a significant share in the electricity market, and if the process of commercialization is to show results, substantially increased levels of private investment are required. Without such investment, there will be no significant cost reductions, which are essential to successful commercialization.

With the kind of hurdles faced by SETs on the path of commercialization there cannot be a straightforward approach to reach the stated objective. There is a need to adopt a well designed integrated approach to facilitate large-scale diffusion of these technologies. Such a planned diffusion process should ultimately aim at a complete commercialization of these technologies without any support from any agency. In other words, such a process should lead to a completely market driven spread of environmental technologies. Private sector alone cannot drive this process without the active involvement of the government, the public sector and the public at large. All the stakeholders need to come together and work towards achieving the goal through public-private partnerships.

2.4 Mistakes in Technology commercialisation

Accoding to Parker K & Mainelli M (2001), there are five 'Great Mistakes' which are typically made in evaluating technology commercialisation process. They are : (i) equating features with benefits; (ii) using 'top-down' market analysis; (iii) Ducking the 'Chicken Gun' Test and (iv) not valuing new technology fully. These can be elaborated as follows:

Features of a technology are appearance, size, rating, etc., whereas benefits are the advantages conferred by the product on the user. The benefits could be (i) a new capability (e.g., a portable stove); letting the technology do much better than the earlier one (e.g., a computer that saves rework); saving money (usually spending capital to reduce revenue costs). New technology by itself is useless unless it generates new benefits to its users. Hence the market research should be on benefits rather than on technology.

In top-down analysis, it is typically predicted by the technology developers that they can capture five to 10% of the market share with in a couple of years assuming that that the market is some kind of collective institution that decides to give a certain percentage of its business to them. They forget that purchase is a consensual act between the customer and the supplier. What is important is to know "how many customers will benefit from the product and by how much; how many can afford it and how many can we get to in our first year?" In other words the market research should be bottom-up rather than top-down.

To paraphrase, inventors should always try to imagine what real human beings (or birds) will do with their precious technology once they are let loose with it. That's the 'chicken gun' test. Just about all development projects have one. The trick is to spot it and address it early in the development programme. Failing the 'chicken gun' test can be disastrous. So a smart development team will try to anticipate what the 'chicken gun' test of their product might be and check whether they can 'pass' early in the development. Once you've grasped the concept, brainstorming potential 'chicken gun' tests and figuring out ways to pass them is actually one of the most enjoyable parts of the whole development process. Just don't leave it too late.

Usually, investors value technology by performing a discounted cash flow analysis on the first commercial project. In other words they ignore all the other potential applications of the technology. On the other hand, most inventors are only too aware of potential applications, but sometimes need a little encouragement to start developing the first project. There isn't really a 'funding gap', but there often is a severe misunderstanding between the two parties, because they are actually valuing different things. The true value of a technology should be calculated as: (i) the net present value (NPV) of the current project arising from that technology; plus an option to invest in all the other potential projects enabled by that technology.

If the technology developers are aware of the Great Mistakes, there is a greater chance of avoiding and enhancing the projects. Figure 1 shows the savings gained by reducing uncertainty in projects early on. It is important to use staged 'gateways' to reduce uncertainty before authorising the next stage. To achieve sustainable high levels of economic growth technology commercialisation is vital. And to achieve this, avoiding the great mistakes are important.

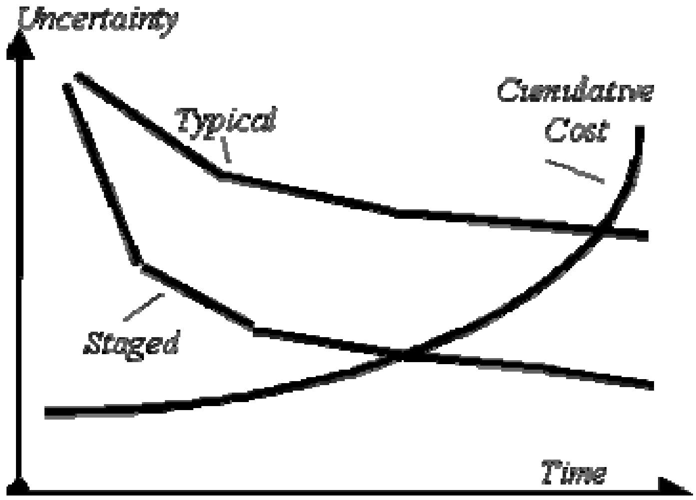

Figure 1: Savings gained by reducing uncertainty

3. Technology diffusion

3.1 The concept

The word *diffusion* was derived at the end of the fourteenth century from the Latin word *diffundere,* which means to spread over. In science, the term *diffusion* refers to the phenomenon of the spread in space or the acceptance in a social environment, over time, of some specific term or pattern. The spatial diffusion is mainly the object of interest of human geographers, sociologists, and development planners. Diffusion in the human-social environment interests researchers of market development and planners of technological development at the firm, regional, and national levels (Kwasnicki and Kwasnicka, 1996). Technology diffusion can be characterised in different ways. One aspect is the diffusion of process technologies measured as the share of production produced by a specific technology. Another aspect is the diffusion of a new product measured as the volume of production of this product or its market share (Jacobsen 2000).

The technologies that are developed penetrate into the society. The rate of penetration or diffusion depends on the following factors (i) innovation itself, (ii) how information about the innovation is communicated, (iii) time, and (iv) the nature of the social system into which the innovation is being introduced

The study of diffusion theory is potentially valuable to the field of energy technology for three reasons.

1. Most manufacturers do not understand why their products are, or are not, adopted. In a very real sense, the underlying causes of technology's diffusion problem remain a mystery to the field. Some blame entrenched bureaucracies and inadequate funding. By better understanding the multitude of factors that influence adoption of innovations manufacturers will be better able to explain, predict and account for the factors that impede or facilitate the diffusion of their products.
2. Technology is inherently an innovation-based discipline. A manufacturer who understands the innovation process and theories of innovation/diffusion will be more fully prepared to work effectively with consumers and potential adopters.
3. The study of diffusion theory should lead to the development of a systematic, prescriptive model of commercialisation. Manufacturers should understand the intrinsic resistance to change as the primary causes of technology's commercilisation.

Technology diffusion is typically modelled as an S-shaped curve over time. The rate of adoption begins slowly, speeds up, and eventually slows down. The fundamental assumption of technological diffusion is that there is an upper limit to the growth of a technology and the growth pattern follows a logistic path. According to this, each technology undergoes four different phases: learning, growth, saturation, and decline. The technological diffusion path starts with a learning curve during the initial stages. The growth phase is usually a logistic substitution, but it usually ends up before being fully saturated. Then the growth rate slows down and declines logistically (Marcetti, 1972).

One justification for the sigmoid curve is that due to a lack of knowledge or confidence in its performance, the probability that a non-user will adopt a new technology increases with its growing popularity. From this intuition, it makes sense that the rate of adoption will be slow in the beginning (before it becomes popular) and decline in the end (when there are few non-users) (Morgenstern and Al-Jurf, 1999). Therefore, it can be assumed that the new technology enters the market and grows logistically and also declines logistically (Figure 2).

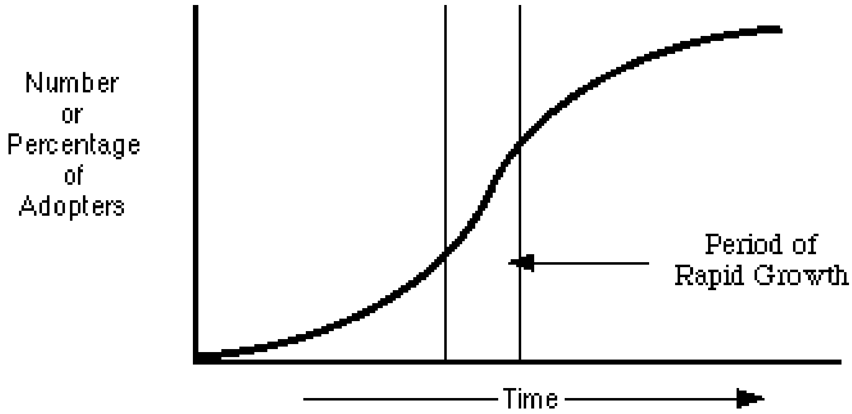

Figure 2. S-curve representing rate of adoption of an innovation over time

Thus, when the technology, which is in saturation starts declining, the newer technology (which is more efficient than the earlier one) gains acceptance and will in turn get saturated when a more superior technology enters the market. This process repeats itself continuously. However, in most cases the new technology does not completely supplant the old one, which still continues to retain a portion of the market. According to Dieperink *et al* (2004), the diffusion of technology is influenced by the following factors:

- The decision-making process of (potentially) adopting actors at the corporate or individual level;
- Corporate and individual characteristics (potential users);
- The influences impinging upon the company (exerted by governments, the market, and society at large);

- Government policy;
- Technical and economic characteristics of the innovation;
- Influences coming from the macro-context such as the price of energy.

Dieperink *et* al (2004) recommend a management strategy that is specific to the target group. That strategy may be summed up as follows: to demonstrate the economic advantage of the technological innovation; to make focused use of information channels (that is, information from suppliers and trade publications); to introduce simple incentives to reward innovative behaviour; and to increase the expertise of the environmental inspectorates.

3.2 The process

In general, diffusion of a technology occurs over time and can be seen as having five distinct stages: (i) knowledge (ii) persuasion (iii) decision (iv) implementation, and (v) confirmation (Rogers, E.M., 1995). According to this theory, potential adopters of a technology must learn about it, be persuaded to the its merits, decide to adopt, purchase it and confirm (satisfy or reject) the decision to adopt the technology. The potential adopters judge a technology based on their perceptions in regard to the following attributes.

(i) Trialability: Can be tried on a limited basis before adoption;

(ii) Observability: Offers observable results;

(iii) Relative Advantage: Has an advantage relative to other technologies (or the status quo);

(iv) Complexity: is not overly complex;

(v) Compatibility: Is compatible with existing practices and values.

As shown in Figure 3, individuals who are predisposed to being innovative will adopt the technology earlier than those who are less predisposed. They are risk takers and pioneers in adopting a technology very early in the diffusion process. At the other extreme are the laggards who resist adopting the technology until rather late in the diffusion process, if ever (Daniel, 1997).

Developing a prior understanding of the diffusion process is very important for promoting environmentally sound energy technologies in general and SETs in particular. A larger impact will be felt when these technologies diffuse across the globe. Another advantage of developing and understanding of the diffusion process is that it will facilitate an accurate assessment of feasible technology replication potential. This information is essential before taking a decision on adopting a particular technology. Also, it is envisaged that the technology diffusion decisions are going to be participatory in nature. The involvement of the stakeholders of diffusion process is important for the success of the programme.

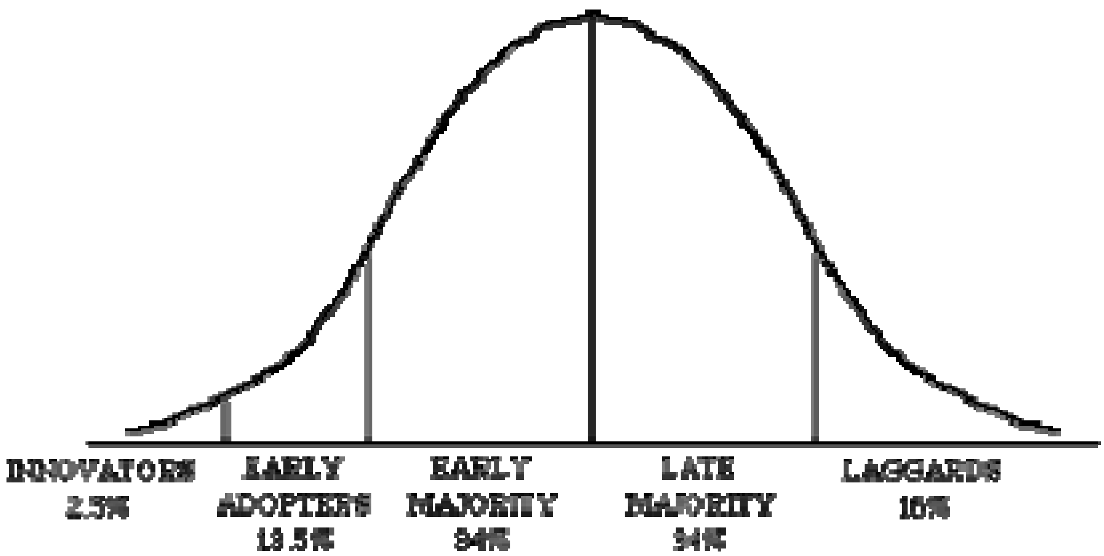

Figure 3: Bell shaped curve showing categories of individual innovativeness and percentages within each category

There are many types of technology diffusion programmes one could adopt. Providing information is at the core of all diffusion programmes and selection of appropriate media is critical for its success. Also prominent are demonstration programmes, which illustrate the technical feasibility and benefits of new technologies. Next step is to build capacities to improve the ability to assess and adapt technologies. The final step is to provide financial assistance to facilitate adoption. Designing appropriate programmes that cater to consumers like small scale enterprises, community organisations and individuals are important because these stakeholders tend to be left out in market driven diffusion processes. Large enterprises could design their own mechanisms to adopt these technologies either to abide by the regulations or as cost cutting/profit maximization measures. Also, with the business model of SET diffusion being propagated, the small scale entrepreneurs can be expected to increasingly participate in the adoption of SETs. The following sections briefly describe the essential requirements for a successful diffusion of SETs.

3.3 The stakeholders

As described earlier, the diffusion/commercialization process of sustainable energy technologies has to pass through a number of hurdles. These hurdles are created by various stakeholders of energy and their involvement is absolutely necessary to overcome them. The effective stakeholder linkage is necessary from initial technology development to the final stage of technology use. The committed involvement of a number of stakeholders is necessary to successfully complete the technology diffusion process. The perception of technology diffusion is likely to be different for different stakeholders. For example, governments and end-users need to understand the costs and benefits of a technology; innovators or the initial adopters need to adapt it to the requirements; manufacturers need to produce it, entrepreneurs need to market the technology while satisfying the end-user needs, and financiers need to appreciate the profitability nature of the projects. Engagement of all key stakeholders is important for successful technology commercialization. The following groups of stakeholders need to come together for this purpose.

3.3.1: Sources and developers of technology: The sources of technology are Individuals/ organizations who carry out scientific research to develop technologies. Typical developers include scientific research establishments, R&D departments within private and public sector firms, government-sponsored research entities, and universities.

3.3.2: Owners and suppliers of technology: These include private firms, state-owned enterprises, and government agencies. Technology developed in the public sector is often ‘spun off’ to the private sector, since the private sector is seen as having better capability to exploit the market potential of the technology.

3.3.3: Buyers of technology: These are the primary stakeholders in the technology diffusion process. Buyers of technology include private firms, state-owned enterprises, government agencies, individual entrepreneurs, NGOs, and even community organizations specifically in the case of SETs.

3.3.4: Users of technology: In the case of commercial technologies, the users are linked only through the transformed end products in the process. The established market mechanisms take care of the needs/aspirations of the users. However, this is not the case with SETs. The user requirements, aspirations, and their views need to be incorporated in the technology diffusion process to make it successful and appropriate. The users of technology could be from industry (private and public), individual entrepreneurs, small industry, community initiatives, individuals/ households, and private and public service establishments.

3.3.5: Financiers of technology diffusion: The financiers are those that lend to technology buyers, or invest in them to enable the buyers to acquire the technology from the suppliers. Organizations involved include commercial banks, international financial institutions, non-banking financial institutions, and individual or institutional investors.

3.3.6: Information providers: These include organizations such as UN agencies that have no commercial interest at stake and whose objective is to facilitate matchmaking between the buyer’s needs and the suppliers’ capabilities by providing objective and unbiased information. This information could include the menu of technology options, sources of technology, case studies where technologies have been used, data and data processing information, and methods for evaluating different options. Other information providers could be technology clearing houses and government agencies.

3.3.7: Market intermediaries: Consultants, NGOs, media, consumer groups, energy service companies (ESCOs), and trade associations fall into this category. Market intermediaries usually can have significant influence on the buyer's decision by providing information about technologies. Depending on the interest of the intermediary, this information may promote certain technologies at the expense of others. In addition, the intermediaries can raise awareness to target groups and other stakeholders, assist technology producers in marketing, help in preparing business plans, bring potential partners together, secure intellectual property rights and licenses, educate financers about technologies, and channelling investment proposals.

3.3.8: Governments: Public authorities set the rules for transactions through regulation, incentives, and frameworks governing imports of technology/foreign capital. When the government perceives that the private costs of technology may not reflect the true costs to society (eg a technology may have environmental externalities), it may be involved in expanding or limiting the range of technologies under consideration.

3.4 The mechanism

Sustainable energy technologies, are among the most complex cluster of technologies for commercialization. First of all, most of these technologies are alternatives for well-established existing technologies and are still evolving, which makes it difficult to decide what exactly should be diffused or commercialized in terms of knowledge, techniques, and hardware. Secondly, these technologies require an interconnecting series of difficult technological choices concerning resources, transformation processes, and transportation systems. These choices are to a significant extent location-specific and cannot easily be addressed on a generic level. Finally, there are a multitude of actors who potentially could become crucial players in local/global markets for these technologies. Because of these complexities, technology diffusion under current conditions has so far been dependent on government driven pathways Commercialization processes with the active involvement of the private sector is yet to take place in a large scale.

Over the past three decades the experience with government driven pathways, including development assistance for sustainable energy and energy efficiency projects in developing countries, illustrates the importance of sustainable market approaches to technology diffusion. In the 1970s and 1980s, development assistance agencies attempted to diffuse SETs like compact fluorescent lamps, cooking stoves, and solar heaters. Many projects were considered failures because of poor technical performance, lack of attention to user needs and local conditions, and lack of replication when projects were successful. Many projects emphasised one-time technology demonstrations that failed to provide incentive structures, to demonstrate institutional and commercial viability, to account for continuing maintenance requirements, to create a maintenance and service infrastructure, and in general failed to generate sustainable markets for the technologies demonstrated (IPCC, 2000). There are many examples of failure in government subsidy driven initiatives in sustainable energy technologies. This has happened irrespective of whether such projects are initiated by private or public sector.These failures highlight the need for an approach that promotes replicable, ongoing technology diffusions aiming ultimately at commercialization rather than one-time demonstrations. The technology adoption decision, which is a precursor to large-scale diffusion, is influenced by many factors. According to Peter et al (2002), the adoption decision is influenced by interest and familiarity. It is also envisaged that finance, product, and supplier characteristics would have a direct effect on the adoption decision. Experience and knowledge is expected to have a positive relationship with familiarity and interest. The predictor variables like motivation, product characteristics, context, government initiatives, demonstration sites, and supplier characteristics influence finance, knowledge, and experience. Any diffusion mechanisms, while developing an effective process of diffusion should take into account these factors and attempt to transform these into favourable factors resulting in an adoption decision.

3.5 The framework

As discussed earlier, in the case of SETs, the diffusion process needs to be induced. For this to happen the key stakeholders have to come together, design an innovative mechanism to induce the consumers to adopt SETs and involve intermediaries in spearheading the entire process towards achieving the diffusion goal. A possible framework under which this process can happen is presented in Figure 4.

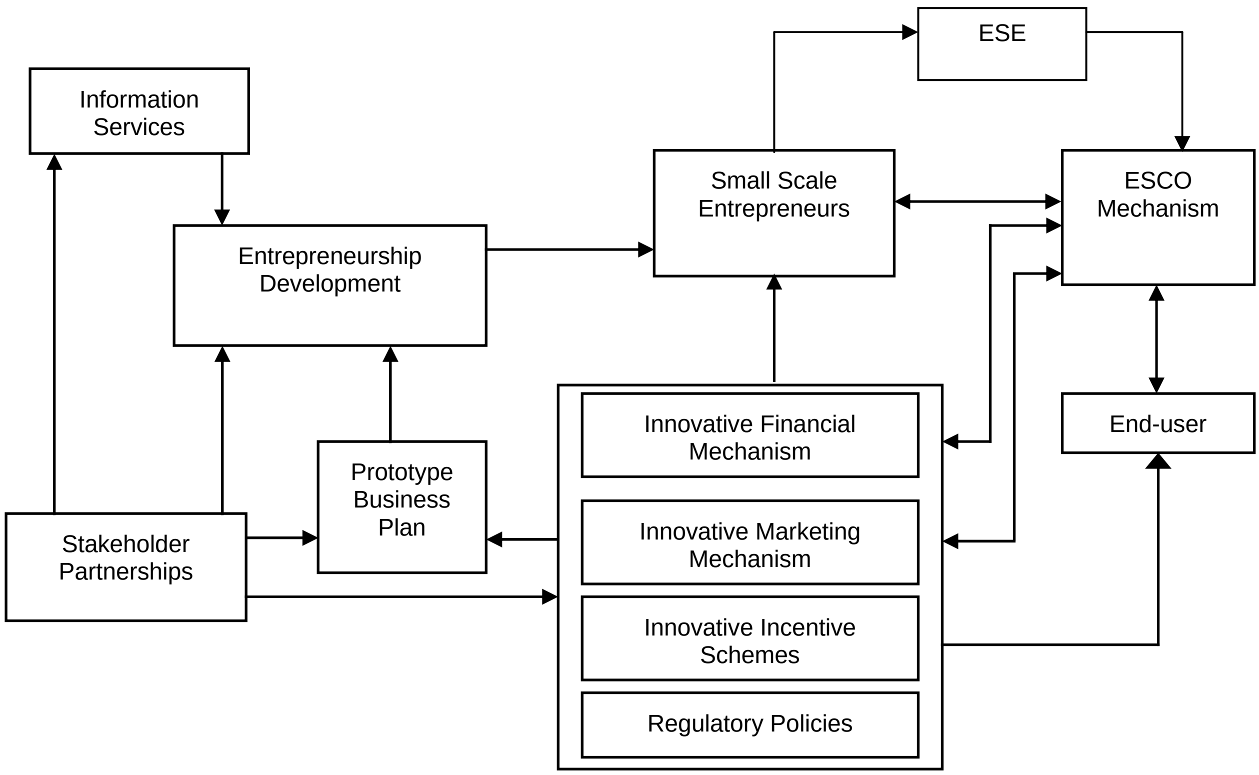

Figure 4: Technology diffusion framework

This effective stakeholder partnership should result in the emergence of innovative mechanisms related to regulatory policies, finance, marketing, and incentives. The innovations mentioned here do not necessarily mean entirely new methods of financing or marketing. Essentially, it represents marginal (and some times radical) changes in established practices of supporting energy efficiency. For example, if conventional financial instruments are inadequate to lend to an energy efficiency project, then there is a need to change the modalities of governing those instruments. In India, for example, banks can only extend loans to individuals, who wants to invest in an efficient device but cannot provide loans to an ESCO to install large number of efficient devices in multiple locations. To overcome this lacuna some changes in rules are required. Once this partnership and innovative mechanisms are established, one of the possible pathways towards diffusion could be the natural attraction of these new initiatives in influencing the consumers to adopt SETs. However, this may not happen with all types of SETs. In order to spread such technologies further initiatives may be required, for example, attracting techno-entrepreneurs to start businesses in energy efficiency either to produce or market energy efficient devices. For this process to succeed, the stakeholder partnership should start target oriented entrepreneurship development programmes, develop technology specific prototype business plans to propagate SETs as attractive business propositions and prepare a pool of entrepreneurs. These entrepreneurs could setup energy service enterprises (ESE) either to manufacture energy efficient devices or to market them or even to sell energy services (energy service companies). Such mechanisms are likely to increase the possibility diffusion of SETs. The subsequent sections discuss these initiatives in a detailed manner.

4. **Policy framework**

4.1 Regulatory policies

The development of any system requires a regulatory framework that serves to create a level playing field. Clear political commitment for its promotion should be translated into supportive policies and regulations that work to create incentives and signal long-term political commitment and greater certainty for investors. But, in the case of SETs, a technological breakthrough, accompanied by a favourable development of the selection environment, is not enough to guarantee the success of a technological innovation. In markets where consumer preferences have been shaped by the long-term use of existing technologies, regulatory policies play a decisive complementary role in the creation and gradual expansion of niche markets, which, through learning mechanisms, facilitate improvement of product performance and adaptation to demand (Menanteau and Lefebvre, 2000).

According to Almeida (1998), market forces are constrained by a variety of transaction types and by the decision-making practices of the agents, in an environment characterized by lack of information and split incentives for adopting SETs. The author argues that public intervention is a necessary condition for organizing the market and promoting these. Government activities to promote environmentally sound technological development must include both supply-push and demand-pull policies during the period spanning pre-commercialization, first commercial use, and lead to adoption (Norberg-Bohm 2000).

There exists a large list of policy initiatives tried to improve the penetration of SETs. According to Almeida (1998), some of the policy options for market transformation to promote energy efficiency are information diffusion through large scale campaigns, creation of standards, quality labelling programmes, adoption of a systemic approach in Demand Side Management (DSM), and collective procurement programmes. It has been observed that the introduction of minimum efficiency standards can greatly increase the speed of technology diffusion. Efficiency standards in association with labelling programmes have been used to create an effective ‘technology forcing’ instrument. Regulatory measures that impose minimum energy performance standards for all available appliances have proved their effectiveness. However, the regulatory approach assumes a strong commitment on the part of public authorities, and preparation times may be long because of opposition from manufacturers (Menanteau, 2003).

If the regulatory measure is considered very strong, then the possible alternative could be to take some policy measures to initiate a voluntary agreement scheme. The principle of negotiating energy efficiency improvements in the framework of voluntary agreements introduces an element of flexibility (differentiation of objectives), which can help limit the risks of ineffectiveness of regulatory measures (Menanteau, 2003). This creates an instrument of 'technology negotiation' compared to 'technology forcing' as discussed above. Voluntary agreements, by virtue of their greater flexibility, which makes them easier to implement, can be an interesting alternative to basic regulations in certain conditions.Negotiated agreements are a more flexible option, which makes them attractive in certain situations, but they must be used as a complementary approach to that of regulatory measures (Menanteau, 2003).

One more possible alternative could be the introduction of innovative pricing policies. These pricing mechanisms have to be designed in such a way so as to penalize certain undesirable products or processes and to support desirable ones in the market place. The introduction of CO_2 taxes to increase prices of conventional fossil based power is a prominent example of such a policy (Martin, 1996).

4.2 Information services

Providing information is at the core of all SET diffusion programmes. Buyers must be aware about the existence of these technologies, their performance characteristics, reliability, capital costs, operating costs, and economic benefits. Buyers must also know how to maintain and service technologies or be aware about the firms that can provide these services. A study by Morgenstern and Al-Jurf (1999) revealed that information programmes make a significant contribution to the diffusion of high-efficiency lighting in commercial office buildings. Additionally, the study found evidence that the programmes are more effective in encouraging retrofits by those who have already invested in advanced lighting technologies than for first-time purchasers. These information services are expected to play a major role in tackling behaviour related barriers among individual adopters. Electronic means are becoming increasingly popular.

The approaches that are appropriate for information dissemination include: establishment of technology clearinghouses and databases through Internet and other means; diffusion through regional centers and trade associations; seminars, workshops, electronic networks, and web sites; training programmes; information kiosks; publications and visual media. The information thus disseminated should include: identification of alternative technologies; benefits of technologies; implementation and investment potential; contribution to environmental goals; technology performance and costs; and barriers to implementation (CTI, 2002).

5. Innovative Institutional and Implementation Mechanisms

5.1 Innovative Financial Mechanism

Financial support will be a critical factor in influencing the spread of SETs. Certainly there is a need for innovative financial mechanisms to support the transfer and diffusion of sustainable technologies. Though a large number of SETs have reached the stage of commercial viability, financing for these technologies still faces numerous challenges. In general, financiers do not show interest in these until there is a sufficient volume of projects with attractive returns. However, one cannot expect to provide large scale business readily. Under such situations, the mechanism of financing needs to be different and the financiers need to accept incentives other than just profits. Some of the innovative initiatives in the direction of setting up alternate financial institutions include (IPCC, 2000):

While most mainstream financial institutions have paid only a modest attention to the environment, a number of smaller organizations or groups within organizations have made it a major feature of their activities. These ‘green financiers’ are usually driven, firstly, by the growing number of investors with concerns about the environment and a desire to see their money invested to take account of these concerns and, secondly, by a high level of personal commitment from the professionals involved. These green financial organizations are highly motivated and prepared to work to overcome the problems either independently or in conjunction with the public sector. Some of the following financial mechanisms seem to be amenable for supporting diffusion of SETs.

5.1.1 Leasing: Leasing is a highly flexible form of finance. It is often packaged as a form of sales financing - i.e., it helps customers of a company buy that company's equipment. Leasing offers potential to be a major source of finance for the diffusion of SETs, particularly to the business community. There is scope to encourage leasing companies to support the diffusion of SETs through selective tax incentives, information sharing and bringing together environmental entrepreneurs and leasing companies.

5.1.2 Venture capital: Venture capital is particularly relevant to the development and transfer of new SETs. Venture capitalists are prepared to back risky investments in return for high returns and will invest in small companies, such as those who have developed new technology, and/or have difficulties raising capital from most other investors. They can play an active role in supporting technology transfer and diffusion.

5.1.3: Micro-credit: Micro-credit is the provision of small amounts of finance to individuals. While the basic concept is the same as traditional banking, the attitude to risk is radically different, because micro-credit institutions are prepared to lend to those ignored by conventional financial institutions - those on low incomes or with no assets. Many believe there is substantial scope for adapting and focusing micro-credit to finance the uptake of SETs at household level. However, some flexibility can be introduced to expand scope of micro-credit financing to include investments in SETs.

A key question is how to increase the number of ‘green’ bankers who are more sensitive to borrowers’ environmental needs and the local socio-economic impacts of various projects. Likewise, how can one change the mind-set of the financial community so that environmental issues can be viewed as opportunities rather than a burden thrust upon them? In this regard, the Clean Development Mechanism (CDM) can be viewed as one opportunity. In the context of CDM as well as other project investments, recognition was given to in-country benefits in the form of significant increases in revenue to the government and the local economy for infrastructure improvement.

5.2 Entrepreneurship development

In order to diffuse SETs in a large scale there is a need for the emergence of a large pool of new age entrepreneurs who are concerned about the environment in addition to making profit in their business ventures. These sets of entrepreneurs will not emerge automatically because the majority does not view SETs as commercially attractive propositions. Therefore it is important to create an enabling environment where such entrepreneurs can emerge and actively play a role in creating businesses in sustainable energy. A climate for stimulating innovation and facilitating meaningful technology diffusion can be created through a change in cultural attitudes and a systems approach that build linkages between education, research, enterprise, finance and the government. Education, training, and research must be geared to relevance, competence, and excellence, to foster entrepreneurship.

Techno-entrepreneurs will be seriously handicapped without the knowledge of: availability of product/process; state-of-the-art, environment friendly energy technologies; national and international Intellectual Property Rights (IPR) laws; national and global marketing arrangements; technology information and expert systems; technical, economic, and commercial viability of projects; and sound principles for managing technology, production, personnel, and finance. The lack of entrepreneurial and technical skills necessary to absorb advanced technologies will be a major hindrance to setup a modern SET business. Some of this human-endowed capacity-building could be developed through activities which might include technical exchanges, demonstration projects, and education, such as the technology training courses.

Some of the activities that may be undertaken to enhance entrepreneurial skills and interest to become an entrepreneur could be:

- To develop and demonstrate selected technologies to enhance competitiveness, replicability, and assimilation;
- To build capacity through programmes of acquiring and upgrading the new skills and experience needed; and
- An information facility for identifying technology ideas from R&D centres and converting them to business opportunities with services that include, among others, a database on technologies and processes including their sources, prices, inputs, and environmental benefits, as well as information on products and processes patents, market information, and business plans.

There should be a mechanism to provide expert help to the entrepreneurs in analyzing the product design, technical feasibility, financial feasibility, energy demand, environmental impact, and so on. The spread of SETs, especially in the rural areas of developing countries, will greatly depend on the strengthening of local entrepreneurial capacity. This would help sustained commercial operation of rural micro- and small-scale energy enterprises that harness energy technologies and provide quality energy services.

5.3 Innovative marketing mechanism

The diffusion of SETs has to face multitude of problems in the competitive environment consisting of traditional energy technologies. Well-established and cheap conventional energy technologies and emerging SETs compete against each other within a market. Capital costs of some SETs are too high to allow massive market competition and diffusion. Also, the final output and the services provided by both sets of technologies are the same. Under these circumstances, the positive aspects of SETs like operating cost savings against current high capital cost and GHG mitigation potential may not be attractive enough to push these technologies. Therefore, it is essential to design innovative marketing mechanisms that create more demand for SETs. This can be made possible though the emergence of SET entrepreneurs as energy service providers.

These entrepreneurs have to develop capacity to provide all the energy related services (lighting, heating, cooling, motive power, video/audio, etc) to the consumers. These services have to be provided either by producing energy on their own or by purchasing it from the supplier. Further, all these services can be integrated and marketed as an 'Energy Service Package'. The pricing has to be based on the whole package and not per unit of energy. This scheme can become successful if appropriate pricing and marketing strategies are adopted. Also, the reliability of the whole process will be high because of the higher responsibility levels of entrepreneurs to maintain the service package, and losses due to failure will be higher compared to pure energy sales. Such strategies can accelerate the diffusion of SET technologies, thereby becoming attractive investment alternatives for the aspiring entrepreneurs.

5.4 Innovative incentive mechanism

The grants and subsidies from the government (either host or donor country) or donations from international agencies in the present form may not effectively contribute to the fast diffusion of SETs. Programmes (for example, utility supported Demand-side Management) created through such support have influences limited to the programme boundaries. The scope is likely to be limited to demonstration rather than having any diffusion effect. This is because, in such schemes, the role of the supporting agencies ends once the project using SET is implemented. The implementing agency may efficiently run the programme till such time the support is provided. Once the programme support is over, there is not always an incentive to continue the process. This is true even for subsidies provided to the energy efficient devices at the time of purchase. These subsidies tend to create a distorted market where consumers are accustomed to lower prices and refuse to purchase the efficient devices at higher prices when the subsidies are removed. It is very important that the programmatic or subsidy support does not end just as an effective demonstration of SET. On the other hand such supports should facilitate a continuous adoption of SETs. However, this will happen only if innovations are brought into these support mechanisms.

An incentive scheme, which ensures the first time purchase of an energy efficient device, its continuous and optimal use, and ready purchase of replacement after its life time should be the preferred one. Such a scheme should not be limited by some programmes/projects, and any prospective adopter should be eligible to enjoy these incentives.

Some of the innovations that could be tried with respect to incentives are:

- *Smart subsidies:* These subsidies influence both the purchase and continuous use decisions. Subsidies need to be used for both discounting the energy efficient device as well as the energy prices for efficient use. However, care should be taken to make these as market ‘attractions’ rather than ‘distortions’.
- *Incentives to succeed* such as reimbursement of expenditure incurred on the purchase efficient device.
- *Mortgaging of energy efficient devices:* The efficient device/technology manufactures should encourage mortgaging of SETs.
- *Values for saved energy:* Credits based on the value of saved energy could be introduced.

- *Tax incentives* for SET purchase and efficient energy use;
- *Energy price discounts* for SET adopters.

Another mechanism consists of 'Green Credits'. The incentives can be paid to the producer/end-user on the basis of per unit of energy produced/saved due to the adoption of SETs. This will encourage them to produce/save more and perform better. Perhaps the most important move in this direction is carbon credits awarded through the Clean Development Mechanism (CDM). CDM provides considerable scope for creative partnerships involving private parties fostering technology transfer for implementing CDM projects. It should, in principle, benefit the developing world through investment in new technology in order to generate certified emissions reductions (CERs) that Annex I parties can use for compliance with their targets.

Finally, loan guarantee schemes can also promote SET projects by small scale entrepreneurs. In order to help technology deployment, governments can introduce loan guarantee schemes to support domestic small business development. They could consist of the central government guaranteeing loans made by domestic banks to the small business sector to encourage the development of that sector.

5.5 Innovative Service Delivery Mechanism – Energy service companies

Energy service companies (ESCOs) are a specific form of technology intermediary that has gained widespread acceptance globally. An ESCO is a company that offers energy services to customers with performance guarantees. Two ESCO approaches that are observed are guaranteed savings and shared savings. In the guaranteed savings structure, the end-user finances the project's initial investment costs from a financier and, in turn, the ESCO guarantees that the energy savings will at least cover the debt services for which the ESCO receives a share in the net savings. However, if the savings fall short of obligations the ESCO assumes the shortfall. In this case, ESCO assumes risks associated with project's performance and the third party financier assumes the end-user's credit risk. In the second approach, the shared savings structure, the ESCO finances the project's initial investment costs, usually by borrowing from a third party financier. In return, ESCO is compensated by a higher share of savings from the project (IPCC, 2000).

ESCOs have been successful in many developed countries. However, the risks and the absence of clear success in developing countries are still issues. Nevertheless, energy service companies are operating or being formed in several developing countries (IPCC, 2000). The ESCO concept is very much appropriate for the spread of SETs. The involvement of ESCO could be either as a performance guarantor, where the under performance risk is taken care of or as a financier it self. Some of the other activities that the ESCOs could involve themselves are: raise awareness to target groups and other stakeholders, assist technology producers in marketing, assist in preparing business plans, bring potential partners together, secure intellectual property rights and licenses, educate financers about technologies in channeling investment proposals.

6. Prototype business plan

It is clear that the diffusion of SETs have to adopt a business approach to make any impact in the energy supply system. This requires attracting the techno-entrepreneurs in the business of SETs. It is an essential practice to prepare a business plan before starting any venture. However, in the case of SETs, since they have not been accepted yet as commercial technologies, it is necessary to market them aggressively. In this regard it may be advantageous to develop prototype business plans for the prioritized SETs emphasising the profitability nature of the projects. This may act as a ready reference document for a prospective entrepreneur.

The prototype business plan is expected to cover all the issues included in a real business plan as follows:

- Description of market environment, analysis of the market for services, segmentation of market if required, customer preferences in terms of prices, quality, payment structure, etc., analysis of market size and growth potential, analysis of competitors, if any.
- Strategies to gain access to market, prioritization of market segments, pricing strategies, after sales service, performance guarantees, market share, production capacity, customer response strategies, discounts, design of sales network, public relations programs, distribution strategies.
- Analysis of comparative advantages, proximity to the market, cost cutting strategies, cost efficient supply chain, availability of skilled labour force, linkage with research institutes.
- Description of the technology, including the special features of the technology, innovation introduced, present stage of development, licensing and patent details, advantages in the technology, reliability of the technology, future development plan and operational plan.
- Explanation of the structure of the company, management team profiles and roles, composition of shareholders, employee structure.
- Analysis of perceivable risks like fluctuations in price, sales, cost overrun, and financial risks.
- Performing profitability analyses through cash flow analysis, IRR, profit and loss statement.
- Creation of a detailed financial plan in terms of estimation of total project cost, share of equity capital, possible share of venture capital, borrowing levels from financial institutions, various kinds of support from government and public sector.

7. Conclusion

Efficient energy supply and utlisation has a crucial role to play in the realm of sustainable development either through conservation of natural resources and environment or through contributing to the economic growth via increases in productivity, advances in technology, improvement in life style, etc. However, this role can become realistic only if there is a paradigm shift in the implementation approaches followed in sustainable energy technology diffusion. Ultimately such an induced diffusion process should lead to smooth transformation of the markets to accept SETs purely on commercial terms.

The past experiences in technology diffusion of SETs have shown that for sustainable technology diffusion, the process should follow a 'business model' approach. In other words, the involvement of the private sector in actual implementation is very important. Governments, NGOs, international agencies, and community groups also need to participate in this process but their role is limited as enablers, supporters, facilitators, and guarantors. The enabling environment created by such partnerships should facilitate creation of business enterprises in SETs.

There may be a large number of small-scale entrepreneurs ready to take up such projects. However, they will not have any interest unless there is a possibility of profit making. To make them viable, the role of governments, international agencies (development banks, UN agencies and governments), NGOs and intermediaries becomes critical. These agencies should play an important role in developing entrepreneurship development programmes, appropriate financial support mechanisms, create incentive schemes and innovative marketing mechanisms aiming at making these small projects profitable. This may lead to a successful SETs diffusion process.

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