1. BASICS OF THERMAL ENERGY SERVICES IN DEVELOPING COUNTRIES

Sustainable Thermal Energy Service Partnerships

Binu Parthan

Sustainable Energy Associates

STEPs
Sustainable Thermal Energy Service Partnerships

FOREWORD

Thermal energy services covered in this research and resource guide involve heat energy for cooking, space heating, water heating, drying and other heat applications in industry, commerce and public services. These thermal energy needs could be delivered as a service through the useful life of the thermal energy device or system to ensure sustained use and associated benefits. Providing universal thermal energy access has been a particular challenge within the energy access agenda with the achievements not keeping pace with population growth. This has resulted in several sub-regions in Asia and Africa having significant thermal energy access deficits.

The popular approach which is being pursued currently in thermal energy access is mainly focussed on biomass based cooking and on delivery of efficient cooking devices. However, the projections indicate that the energy requirements for cooking will decrease whereas future energy requirements for space heating/cooling and water heating will increase in developing countries. A global survey was carried out as part of the research with responses received from about 30 organisations consisting of a range of development agencies, research institutions, policy makers and practitioners.

The survey results show that biomass based technologies remain as the focus with direct product delivery as the most popular approach. The survey also highlighted the urban bias in the current efforts which seem to bypass the rural areas. There are alternate approaches that focus on a range of conversion technologies such as solar water heaters, liquefied gas, electricity and using communication and finance ecosystems to offer longer term and sustainable solutions. There seems to be a clear case for rethinking the current approach to thermal energy access.

- Binu Parthan, 2017.

Acronyms

IEA	International Energy Agency
CDD	Cooling Degree Days
HDD	Heating Degree Days
LPG	Liquefied Petroleum Gas
PAYG	Pay-As-You-Go
PPP	Public-Private Partnership
SME	Small and Medium Enterprises
SWH	Solar Water Heater

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STEPs website: http://stepsproject.net/

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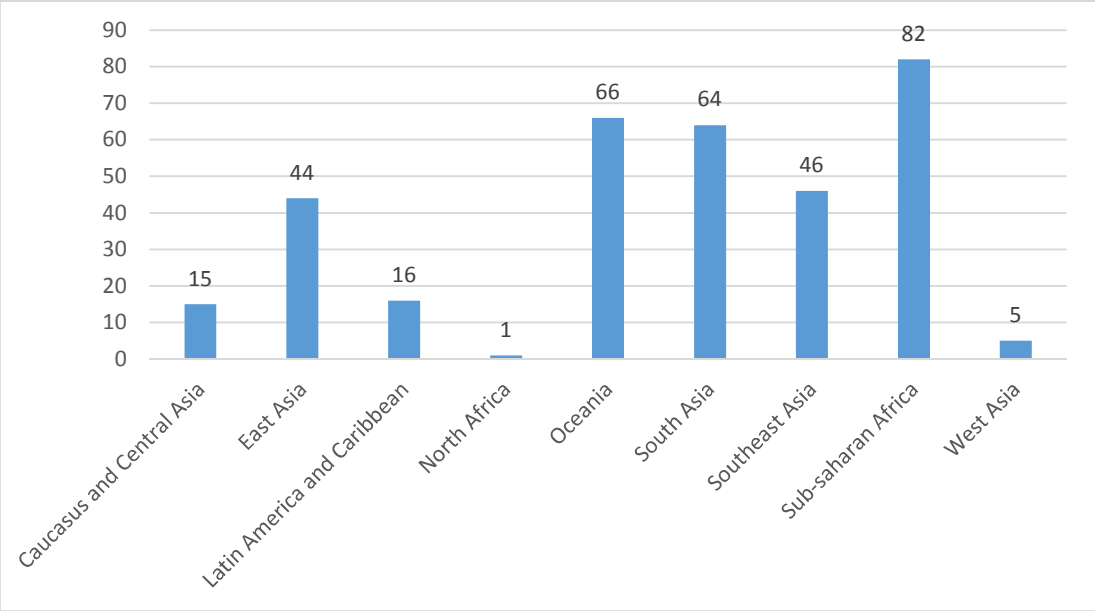
1.0 – What Are Thermal Energy Services?

1.1 Why Are Thermal Energy Services Important?

There were about 2.9 billion people in 2015 without access to modern thermal energy services[1] in developing countries, the number having increased from 2.8 billion in 2010 (IEA and World Bank, 2015). The majority of 1.9 billion of these people are located in developing countries in Asia. The countries with the biggest thermal energy access deficits also feature several Asian countries such as India, China, Bangladesh, Nigeria, Pakistan etc. (IEA and World Bank, 2015). However when you look at sub-regions within continents and the share of population without access to modern thermal energy service, the regions with the biggest access deficits are Sub-Saharan Africa followed by Oceania, South Asia, South East Asia etc. This is illustrated in Figure 1.

Figure 1. Thermal Energy Access Deficits Aggregated by Regions (% of population)



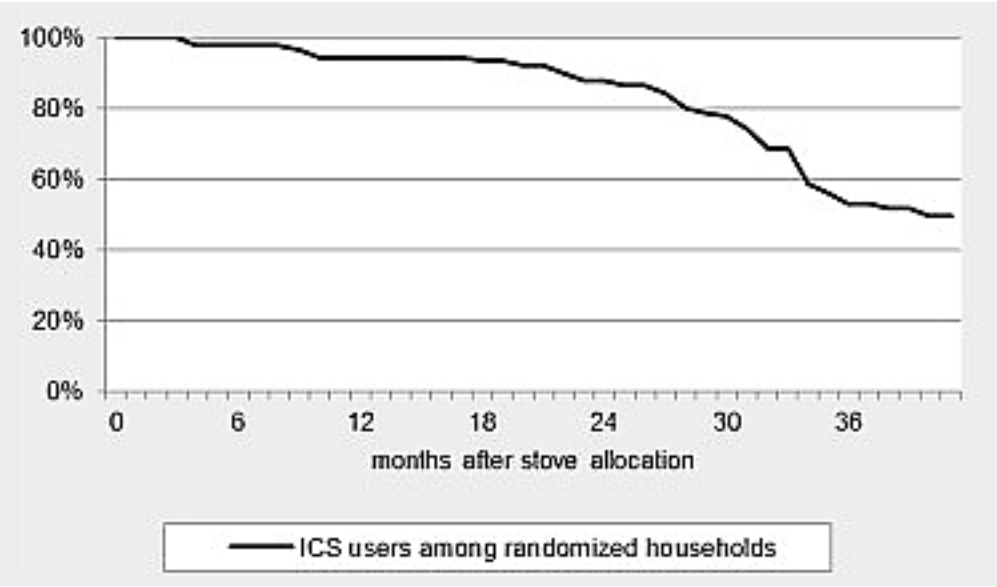
Source: IEA and World Bank, 2015.

This challenge has so far been addressed through efforts that were primarily focused on cooking and related technologies. The approach has addressed the costs of target users acquiring the new technologies. The business models are also mainly focussed on manufacturing and supply of products with governments and development agencies supporting purchases by end-users through capital and interest subsidies.

[1] Generally accepted in energy and development community as access to non-solid fuels.

This approach assumed that the clean thermal energy technology once diffused as subsidised pilot devices would continue to be used and replaced by the end-users. However experience and studies (Bensch and Peters, 2015) show that the use of new technologies decrease with time and many of the developing country households that adopt new cooking technologies do not continue the usage over a period of time and switch back to the traditional cooking option. Results from a study in Senegal illustrated in Figure 2 show that about half the users had stopped using the new cooking technology after 26 months (Bensch and Peters, 2015).

Figure 2. Decline in Usage Rates of Efficient Cookstoves in Senegal (% of users)



Source: Bensch and Peters, 2015

However major gains have been made in the promotion of Solar Water Heating (SWH) using solar thermal collectors in many developing countries. In a large number of countries with electricity access, hot water is increasingly being supplied by SWH systems. These have been shown to be more economical than electric geysers in many developing countries, especially countries that lie between the tropic of cancer and tropic of Capricorn which receive considerable amounts of sunshine. China alone had more than 44 GWth of solar thermal collectors which represented more than 80% of global installed capacity (REN21, 2015). Other developing countries with energy access challenges such as Brazil and India also have large solar thermal collector installation base of 965 MWth and 770 MWth respectively (REN21, 2015). Many developing countries have also developed relatively large installation base for solar thermal collectors.

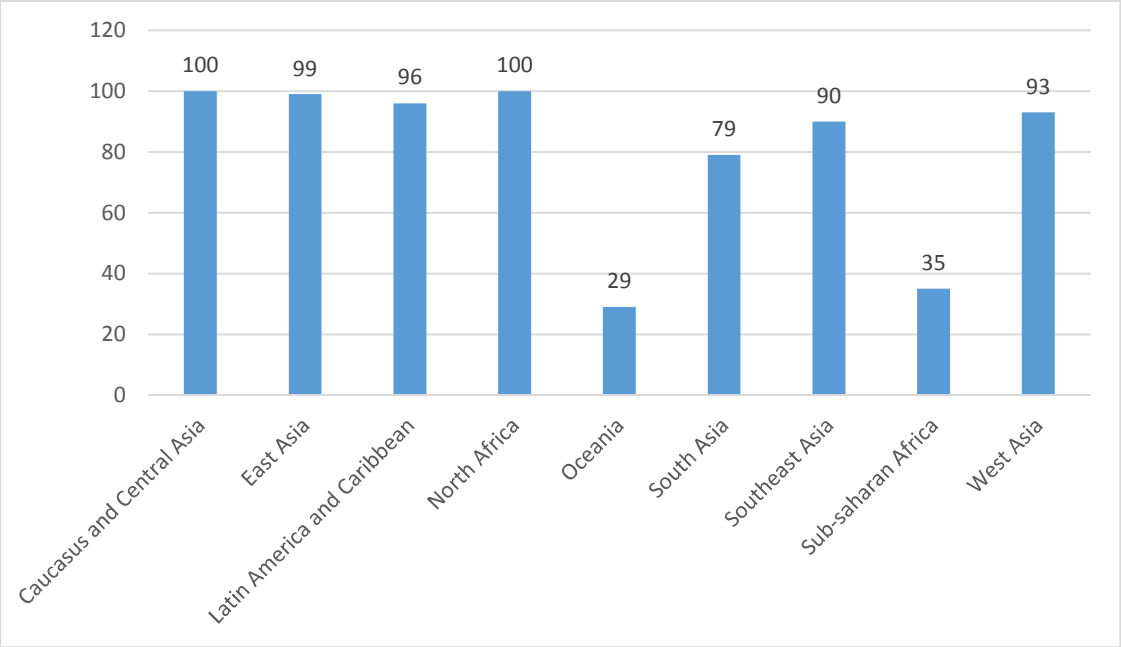
Biofuels are also used extensively in many developing countries with the biofuel use being concentrated in the transport sector. Among developing countries, Brazil produces about 30 billion litres of biofuels which amounts to over 23% of the global production (REN21, 2015). Other developing countries such as China (3.9 billion litres), Argentina (3.6 billion litres), Indonesia (3.1 billion litres) all have high levels of biofuel production. Biofuels such as ethanol and methanol can be used for cooking with alcohol stoves. Several alcohol based cooking programmes have been popular in refugee camps and also in countries like Ethiopia, Haiti, Nigeria, Mozambique, Brazil, Madagascar, Kenya etc.

Liquefied Petroleum Gas (LPG) is a clean gaseous fuel which is already popular in developing countries for cooking applications and the use of which is increasing steadily. LPG is the primary cooking fuel for more than half the households in 33 developing countries (Kojima/World Bank, 2011). LPG use increases with rise in income levels as well as level of education of the women in the households. A major barrier to increased levels of LPG use in developing countries have been the initial costs of the LPG connection as well as the need to buy LPG in large cylinders resulting in high investments. Such barriers have been overcome by Pertamina in Indonesia, Pimagas in Kenya and under the national government programme in India. LPG has also been used for space heating/cooling applications in developing countries with higher levels of Heating Degree Days (HDDs) or Cooling Degree Days (CDDs).

Electricity has also been used for cooking, hot water and space heating/cooling in many countries around the world especially in industrialised countries. Use of electricity is also high in developing countries such as South Africa where electricity is the main cooking energy source (Leach and Oduro, 2015). Use of electricity for cooking holds promise in many developing countries as the rates of electrification increase and as efficient electric cooking options such as inductive cooking, electric rice cookers and micro-wave cooking become more and more popular and more processed/pre-processed food markets available in developing countries, especially in urban areas.

The electrification level of various regions is shown in Figure 3 and as can be seen, electrification levels in all regions are high and increasing. However the electrification levels remain low in Oceania and Sub-Saharan Africa at 29% and 35% respectively. Despite the low electrification levels, the urban electrification levels in Oceania and Sub-Saharan Africa are higher at 71% and 69% respectively and offer opportunity for use of electricity for thermal energy in urban areas.

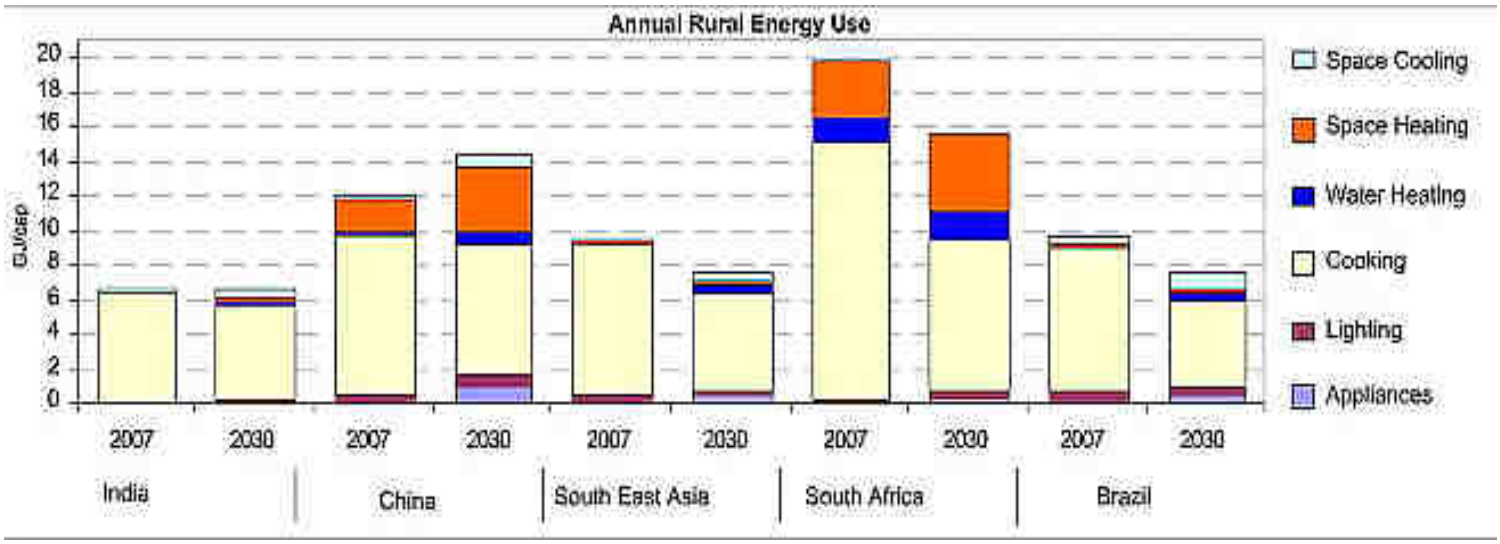
Figure 3. Electricity Access Aggregated by Regions (% of population)



Source: IEA and World Bank, 2015.

The general trend in many parts of the world shows that energy requirements will continue to decrease in the future due to improvements in end-use energy efficiency. From a thermal energy perspective, the energy requirements for cooking is likely to decrease but the energy requirements for space heating, space cooling and water heating is expected to increase in developing countries as is illustrated in Figure 4. However cooking is likely to remain as the most significant thermal energy use. It may also be noted that electrical energy use for lighting and appliances is likely to be lower than these thermal energy uses.

Figure 4. Rural Energy Use Projections in Selected Developing Countries



Source: V. Daioglou et al., 2012.

1.2 Current Status of Thermal Energy Services

As the published materials on thermal energy services were limited, a global survey was carried out by the STEPs team during the one period August 2014 to August 2015 where questionnaires were sent out to 69 organisations covering development agencies, research institutions, private organisations, practitioners, policy makers and researchers who were either involved in developing and implementing energy access programmes or carrying out research. The geographical focus of the survey was Sub-Saharan Africa followed by Asia. The questionnaires were followed up with phone interviews as well as site visits to elicit maximum responses from the targeted organisations and researchers. A total of 30 responses have been received which provide a good basis to characterise the various efforts at the international and local level in providing thermal energy on a service mode. The details of organisations which responded to the survey are detailed in Table 2.

Table 2. Institutions Responding to STEPs Global Survey on Thermal Energy Services

Organisation[2]	Description	Location / Geographic Focus	Involvement in Thermal Energy
Africa Clean Energy www.africancleanenergy.com	Private sector stove manufacturer	Lesotho, Sub-saharan Africa	Manufacture and sales of high-efficient biomass cook stoves
Ashden Trust www.ashdentrust.org.uk	Using awards to highlight exemplary clean energy initiatives	United Kingdom, Global	Recognising efficient biomass Cookstoves, solar drying of agro-produce, solar space heating
Bright Green Energy Foundation www.greenenergybd.com	Not-for-Profit implementing energy access solutions	Bangladesh	Promoting interventions with efficient Cookstoves and Biogas digesters
ECOWAS Centre for Renewable Energy and Energy Efficiency www.ecreee.org	Regional intergovernmental organisation	Cabo Verde, West Africa	Cookstoves, LPG, Solar Thermal
Emerging Cooking Solutions www.supamoto.co.zm	Private Thermal Energy Service Company	Zambia	Since 2012, offering Cookstoves and biomass fuel pellets based on service contracts
Energy for Impact www.energy4impact.org	Not-for-Profit international organisation working on energy access issues	United Kingdom, East and West Africa, Caribbean	Implementing initiatives on Cookstoves, biomass briquettes and LPG
Gesellschaft für internationale Zusammenarbeit; www.giz.de	Bilateral Development Agency	Germany, Global	Solar Thermal, Improved Cookstoves
Global Alliance of Clean Cookstoves www.cleancookstoves.org	Public-Private-Partnership	United States, Bangladesh, China, Ghana, Guatemala, India, Kenya, Nigeria, Uganda	Clean Cooking
Imperial College www.imperial.ac.uk	Education and Research Institute	United Kingdom	Solar energy
International Finance Corporation www.ifc.org	Private Sector focussed arm of the World Bank	United States, global	Financing manufacture and production of clean Cookstoves and clean fuels
International Institute for Applied Systems Analysis www.iiasa.ac.at	International, Non-Profit, Independent Research Institute	Austria, South Asia, Pacific, Sub-Saharan Africa and Central America	Research on cooking energy choices

[2] In alphabetical order.

Organisation[2]	Description	Location / Geographic Focus	Involvement in Thermal Energy
International Lifeline Fund www.lifelinefund.org	Non-profit water and sanitation and clean cooking practitioner	United States, Uganda, Kenya, Haiti	Clean Cookstoves, LPG
Inyenyeri www.inyenyeri.org	Private Thermal Energy Service Company	Rwanda	Offering Cookstoves and biomass pellets based on service contracts
M-Kopa www.m-kopa.com	Private Energy Access Service Provider	East Africa – Kenya, Tanzania, Rwanda	Offering Biomass Cookstoves on a 'Pay-As-You-Go' mode
NuRa Energy www.nura-energy.co.za	For-profit energy service company	South Africa	Solar Home Services, LPG and Cookstove sales.
Practical Action www.practicalaction.org	Non-for profit working on energy access, climate change and other development issues	United Kingdom, global	Promoting interventions with efficient Cookstoves and Electric Cooking
Prime Cookstoves AS www.primestoves.com	Private Sector Stove manufacturer	Norway, Indonesia, South Africa, Russia, Zambia, Senegal, Cambodia	Efficient Cookstoves manufactured in Indonesia and distributed globally in target markets
SELCO www.selco-india.com	For-profit energy access service provider	India	Distribution and installation of solar water heaters and Cookstoves
SESI International www.sesinter.com	For profit engineering and consulting company	New Zealand, Afghanistan, etc.	Development of 1 MW solar mini-grid in Afghanistan providing both electricity and thermal energy services
Simpa Networks www.simpanetworks.com	Private sector energy access service provider	India	No current involvement
Small Scale Sustainable Infrastructure Development Fund www.s3idf.org	Social Merchant Bank financing clean energy practitioners	United States, India	Promoting pressure cookers and LPG as alternatives to biomass based cooking
SNV www.snv.org	International non-for-profit active on energy, agriculture, water and sanitation	Netherlands, Sub-saharan Africa, South-East and South Asia and South America	Implementation of projects involving, biogas, efficient biomass Cookstoves and Solar water heating
Stellenbosch University www.sun.ac.za	Education and Research Institute	South Africa	SHWS research and training
Stove Team International www.stoveteam.org	Not-for-Profit Stove manufacturer and thermal energy practitioner	United States, El Salvador, Guatemala, Honduras, Mexico	Efficient cook stoves manufactured in Latin America.
The Energy and Resources Institute www.teriin.org	Non-profit, independent research institution	India, global	Promoting efficient cook biomass stoves and biomass gasifiers for process heat.

Organisation[2]	Description	Location / Geographic Focus	Involvement in Thermal Energy
United Nations Economic and Social Commission for Asia-Pacific www.unescap.org	United Nations Regional Commission	Asia and Pacific	Promotion of 5P – Pro-Poor Public-Private-Partnership projects on energy access. Geothermal energy and thermal energy technologies
United Nations Industrial Development Organisation www.unido.org	United Nations Agency for Industrial Development	Austria, Global	Thermal energy from biomass residues for industrial processes for SMEs
Vuthisa Technologies cc www.vuthisa.com	Private Sector energy access products and technology reseller	South Africa	Cook stoves, Biomass briquettes, solar lighting products
World Bank www.worldbank.org	Multilateral Development Bank	United States, Global	Cookstove programmes and also coverage of LPG and SHWS as part of their programmes
World LP Gas Association www.wlpga.org	Global Private and Public Industry body	France, global with 220 members in more than 125 countries	Promoting cleaner cooking through switching to LPG from biomass

As is evident in Table 2, all major global agencies and initiatives active in thermal energy issues in the programming, finance and research spaces have responded to the survey. In addition a number of key thermal energy practitioners from the not-for-profit and private sector primarily from Sub-Saharan Africa and Asia have also responded to survey. Based on an analysis of the feedback received from these key institutions, the following inferences can be made.

1.3 Technology and Services

The focus of thermal energy initiatives and practitioners as evidenced in the survey remain on biomass with over 73% surveyed actively involved, which has been the traditional fuel for cooking, water heating and space heating in developing countries. This focus may be justified as biomass is generally available free and can be gathered by investing free time available, particularly by women. LPG has made limited market penetration in Sub-Saharan Africa compared to Asian countries and the diffusion is more focussed in urban and peri-urban areas and with wealthier sections of the communities and with institutions – both public and private.

Electric water heating has been widely practiced in households and institutions and are increasingly being replaced by SWH Systems. SWH Systems have not been promoted significantly by international development programmes and agencies although the thermal practitioners have been reselling these to institutions and wealthy households. Electric cooking and space heating is also emerging as a significant option for wealthy communities and institutions and in African countries like South Africa it is the major source for thermal energy.

Some instances of drying of agricultural produce using solar dryers were noted in the survey as well as biomass for industrial process heat in Small and Medium Enterprises (SMEs). Also noted was the use of solar for space heating.

Cookstoves have been promoted through capital subsidies as the household level users have been slow to adopt the technology even after promotional efforts and clear evidence of benefits. However there seems to have been a higher level of demand for efficient cookstoves from institutions. For LPG and SWH Systems, the acceptance levels are much higher but with the initial investment in technology and conversion equipment acting as the barrier. It was also noted that a number of practitioners, especially in Sub-Saharan Africa such as Rwanda and Zambia are increasingly offering solutions which combine efficient conversion devices and fuels on a contract basis. These have generally been densified biomass residues – such as pellets and briquettes in combination with efficient cookstoves as a package.

1.4 Geographic Location

It was noted during the survey that over 70% of the thermal energy product and service providers focus on urban areas as their markets. The availability of a higher concentration of customers and minimisation of transaction costs for marketing, delivery and service are considered to be a major driver. Another important factor for the markets to focus on urban areas could be the higher income levels in urban and peri-urban areas with a higher concentration of wealthier households, commercial and industrial enterprises and public institutions. The storage and distribution points for LPG are also concentrated in urban centres due to similar user density and income factors.

The SHW Systems are retailed mainly to electrified households as an alternative for electric geysers and is geographically limited to electrified areas often with water distribution. Some of the new initiatives have tried to offer services beyond urban areas by leveraging the mobile network and mobile money services coverage. This is increasingly helping in extending the coverage of thermal energy services to rural areas and at the same time able to manage the transaction costs. Electricity based cooking has been generally limited to urban areas and to wealthier households, commercial and industrial enterprises and public institutions. There have also been past attempts at electric cooking in households and enterprises in rural areas by some of the surveyed organisations.

As evidenced in the survey, the geographical distribution of thermal energy services and products as above does not vary across African and Asian markets. The scale and the market penetration levels are higher in Asia due to larger population centres, lower unit costs of thermal energy equipment etc. The diffusion of SWH systems has been quite high in Asia due to the population density, manufacturing base and also higher level of electric geyser replacement/alternatives.

For the LPG services, there is a significantly higher level of penetration and use in Asia driven by a Public-Private-Partnership (PPP) model where the public sector in many countries such as Indonesia, India etc. have made significant levels of investment in storage and distribution infrastructure for LPG and subsidising the cost of initial equipment. The distribution is through private franchisees which serve both the urban and rural areas. Countries such as Ghana in Africa are following this model setting ambitious targets for LPG in thermal energy use.

Similarly the survey revealed that in the case of mobile money based services, African countries have a more developed ecosystem for mobile money based services where many establishments accept mobile money for goods and services. Electricity, Lighting and thermal energy service providers are also taking advantage of this mobile money ecosystem to offer energy services in areas that have mobile telephone coverage. For a number of reasons mobile money has not been as widespread and popular in Asia as it has been in Africa, especially East African countries such as Kenya, Uganda, Tanzania etc. and therefore only few institutions/locations surveyed were using mobile payments as energy service payments.

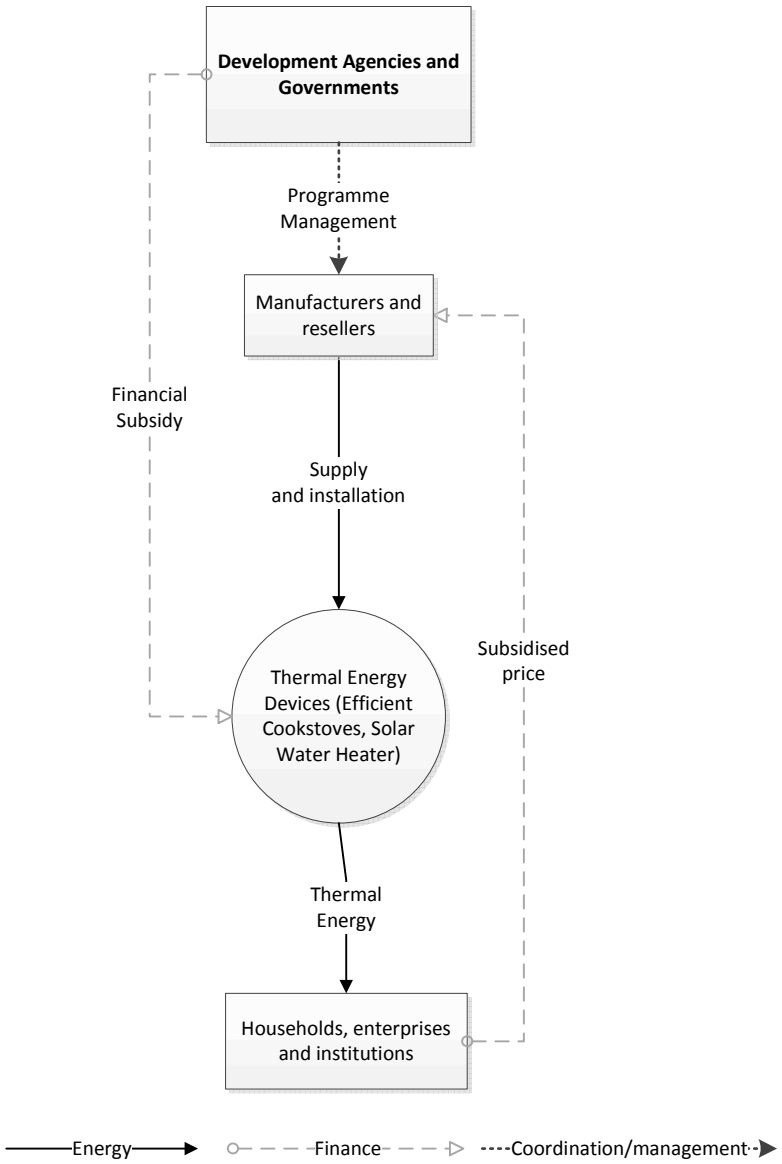
1.5 Current Approaches

A number of different approaches have been adopted by the organisations surveyed in addressing the challenge of thermal energy for cooking, space heating/ cooling, water heating and small-scale drying etc. In terms of the institutional, business and financing structures these can be grouped into three as direct delivery, fuel and energy sales and hire-purchase/financing. These different approaches are illustrated and described below:

Direct Delivery

This has been the most popular mode of diffusion of thermal energy solutions; in this model the approach has been to deliver a thermal energy service product such as an efficient cookstove or a SWH as a replacement to traditional biomass or electric geysers as the case may be. This approach assumes that once the users are introduced to a superior technology they will fully replace the existing inefficient equipment and switch. Many international development agencies, non-profits and national governments have all used capital subsidies as a financing mechanism to aid the diffusion of these devices as the cost of these efficient/renewable alternatives are higher than the conventional thermal energy devices. It is also assumed that the users will continue to use the system through to its useful life and replace with a similar system thereafter. The direct delivery model has been defined on the basis of the research and is illustrated in Figure 5.

Figure 5. The Direct Delivery Approach



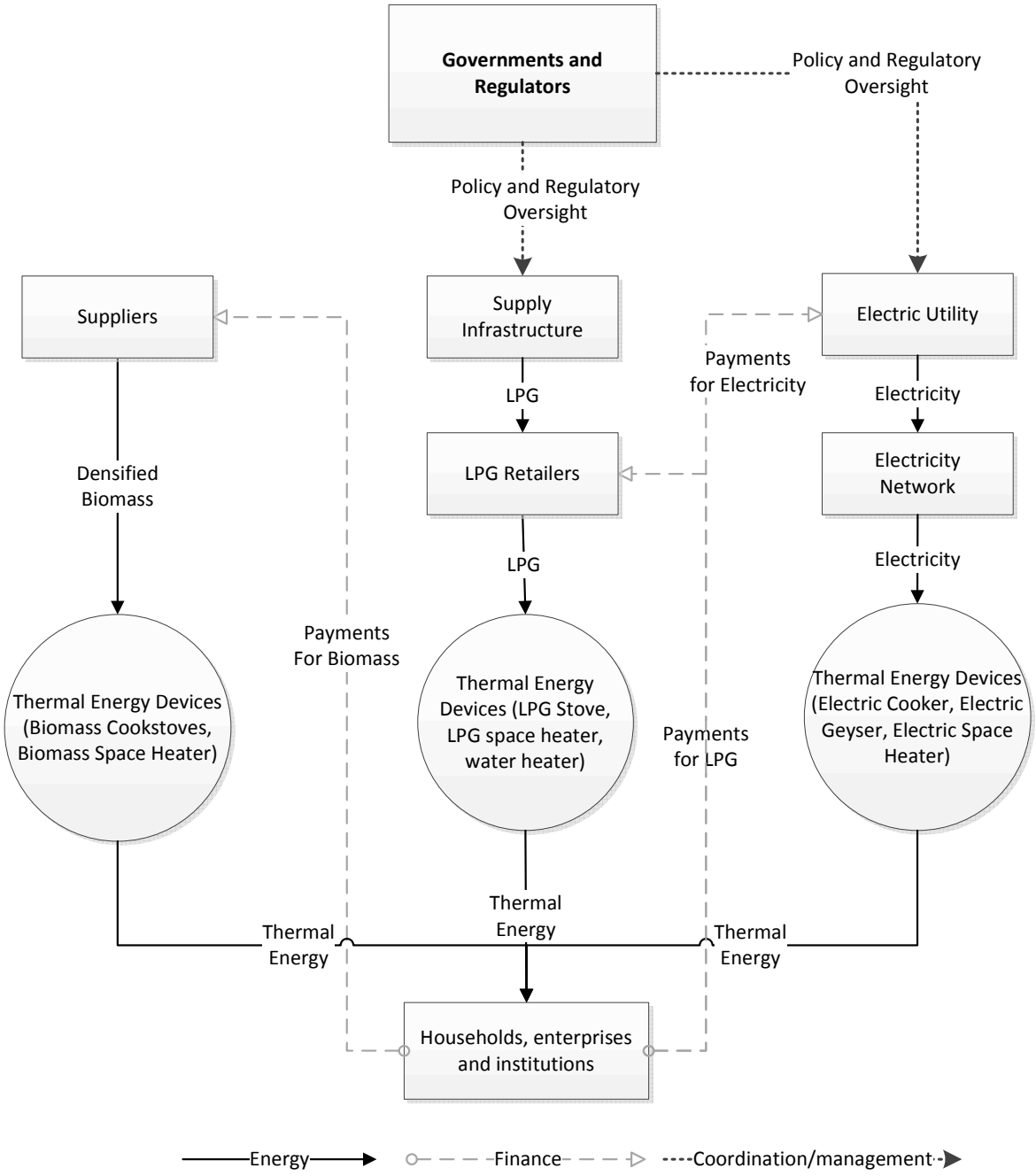
Author: B. Parthan, 2016

Fuel and Energy Sales

In this model there remains a continuous relationship between the user of thermal energy and the service provider often on the basis of a contract. The more established approaches have been where users consume electricity of LPG and the users either pay before or after use. The energy conversion equipment such as stoves, heaters, geysers, radiators etc. all need to meet safety and often performance or efficiency standards. The electricity and gas suppliers are regulated by the governments or independent regulators and operate in a clear policy environment.

A third form of such an arrangement is through a contract/relationship for supply of densified biomass such as fuel pellets or briquettes. Such arrangements for pellets, briquettes and woody biomass have existed through formal and informal means targeting commercial enterprises, institutions and even households in the past for larger scale applications. This is increasingly being offered at the household level in urban and rural areas and the pellets or briquettes are supplied in sacks to the users. The fuel and energy sales model defined on the basis of the research is shown in Figure 6.

Figure 6. The Fuel and Energy Sales Approach

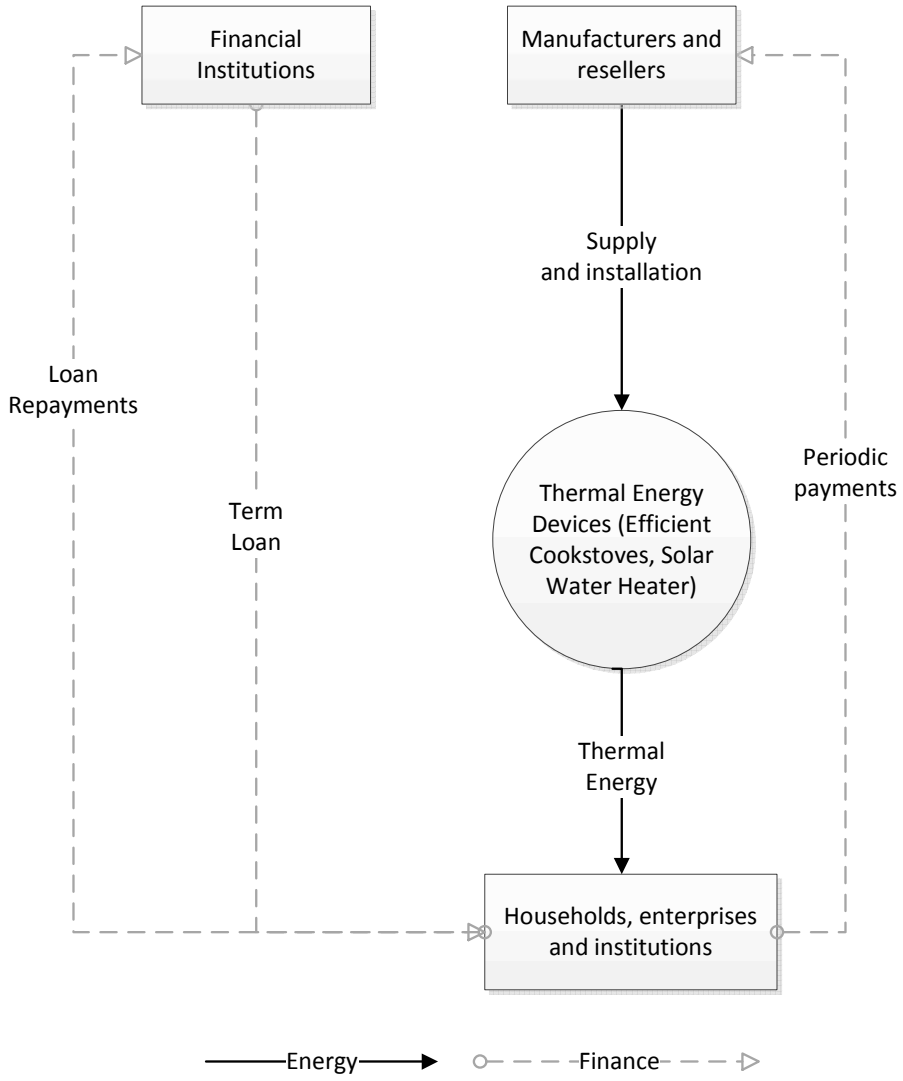


Author: B. Parthan, 2016

Hire Purchase and Financing

In this model cost of the thermal energy device or system is fully recovered from the user and over a longer period of time. This is either achieved through the use of hire-purchase schemes where the user get delivery of the system by making an upfront payment and then makes regular periodic payments after which the ownership of the system is transferred to the user. These finance-product packaging has also been called Pay-As-You-Go (PAYG) or progressive purchase. In a variant of this model a financial institution offers a term loan to cover a major share of the system and the user repays the loan to the financial institution or bank. The model with the financial institution is more prevalent in regions with robust micro-finance ecosystem or for larger enterprise or institutional systems and not relevant in many African countries. In this model while the user pays the full cost, the payments are deferred to address the initial incremental costs associated with obtaining the efficient thermal energy system. This model with both the variants is illustrated in Figure 7.

Figure 7: Hire Purchase and Financing Approach



Author: B. Parthan, 2016.

2.0 – Conclusions

The conclusions that can be drawn from this research and the global survey of institutions engaged in energy access are as follows:

- Energy access and thermal energy access in particular continues to be a major challenge globally and specifically in developing countries. The gains made in providing thermal energy access in recent years has been offset by population growth;

- Current initiatives at various levels have targeted delivering more efficient devices to allow use of biomass resources with an emphasis on cooking. Other thermal energy needs such as water heating, space heating/cooling and process heat for commercial, industrial and public service uses have not received the same level of efforts and attention;

- Apart from biomass based technologies, options such as solar water heating, solar drying. LPG, electricity, biofuels etc. could also play an increased role in increasing access to thermal energy. It is also projected that space heating and cooling as well as hot water requirements are expected to increase in the future in developing countries whereas cooking energy requirements are likely to decrease;

- The global survey carried out by the project received a strong response from key global institutions and initiatives active in thermal energy as well as from major thermal energy practitioners in the private and non-for-profit sector from Africa and Asia;

- The survey reaffirmed that the focus continues to be on efficient cooking based on biomass but also an increasing share of SWH Systems and a limited but significant role for electricity as a means for thermal energy. A number of practitioners are also making available densified biomass as fuels to users;

- Due to considerations of market density, income levels and cost optimisation, thermal energy access efforts are focused in urban areas of Africa and Asia, with the higher scale of efforts in Asia. Expansion of communication and electricity networks is helping to offer thermal energy services to rural areas as well, particularly in Africa;

- The various approaches in thermal energy access can be grouped into direct delivery, fuel and energy sales as well as hire purchase and financing. Fuel and energy sales model ensures sustained modern thermal energy use and the hire-purchase and financing approach is also more sustainable than the direct delivery approach;

- While delivering thermal energy services that go beyond biomass based cooking in a service mode on a sustained basis appears to be a challenge considering the current status, there seem to be a number of innovative and scalable models and initiatives that offer promise;

- The STEPs project team has carried out research and analysed the technology, finance, business, policy and regulatory aspects of promising models to identify best practices and to develop features which could be developed into a partnership model for thermal energy services.

Questions and Answers

What are thermal energy services, and why are they important?

Thermal energy services in the context of the STEPs project research refer to energy services for cooking, water heating, space heating and cooling. Energy services for low-grade industrial applications such as drying, heating and cold storage are also considered, targeting small-scale industrial enterprise and public service use. Thermal energy services often involve the presence of a service provider, such as an energy service company, entering into an agreement with an end-user to provide energy services. This is in contrast to an equipment supplier, supplying energy equipment without a longer service arrangement.

Therefore, thermal energy services can be defined as providing energy access from any energy sources to meet thermal energy needs for household, commercial, industrial and public service use on a service mode through a service provider.

Approximately 2.9 billion people currently do not have access to modern thermal energy services, instead relying on energy sources such as gathered biomass for their thermal energy needs. The majority of these people live in developing countries in Asia, around 1.9 billion. However, Sub-Saharan African countries have the greatest proportion of population lacking access to modern thermal energy sources, over 80%. Servicing these communities with modern thermal energy services is a vast extant market opportunity, and a pressing developmental need.

What technologies are available for thermal energy services in developing countries?

There are a wide variety of technology options available for thermal energy services in developing countries. The STEPs project is specifically focusing on technologies for cooking, water heating and space heating/cooling. Some of these technologies are more widespread than others: during the primary research conducted under the project over 70% of surveyed organisations had some involvement in sustainable biomass fuels, for example.

Technology options available for cooking include improved cookstoves, either fired with traditional biomass fuels or charcoal, as well as LPG stoves for household or institutional use. Solar water heating technologies have also been considered during the project, both flat-plate and evacuated-tube solar collector designs. Finally, biogas technologies for household or small-scale industrial (agricultural) use have been researched, as well as heat pump technologies for cooling and refrigeration.

What approaches are currently being used to deliver thermal energy services to consumers?

There appear to be three main approaches currently used to deliver thermal energy services to consumers in developing countries. These are direct delivery, fuel and energy sales, and hire purchase and financing. Direct delivery models involve a company directly selling energy service equipment to consumers, usually on a cash-purchase basis. This method can also involve distributing thermal energy products directly to consumers on a subsidy basis. Fuel and energy sales models involve an energy service company entering into a longer-term relationship with consumers by providing fuels or other energy sources, commonly on a contract basis. Consumers can pay either before or after consumption for these fuels (electricity, LPG). Other arrangements include contracts for supply of fuel sources such as densified biomass, pelletised biomass or briquettes.

Finally, hire-purchase and financing schemes have also been used to deliver thermal energy services. This model involves the cost of the thermal energy service or product being recovered over time in full from the consumer on a weekly/monthly basis. This can be through a hire-purchase scheme, where the consumer receives a thermal energy device and repays the cost over time to the energy service company, gaining ownership of the system when the cost is repaid. A variant of this model can be where a financial institution offers a term loan to cover a major share of the system and the user repays the loan to the financial institution or bank. This is more common in regions with a robust micro-finance infrastructure, for example countries like India or Bangladesh.

References

Bensch, G., Peters, J. (2015) The intensive margin of technology adoption – Experimental evidence on improved cooking stoves in rural Senegal, *Journal of Health Economics* 42, pp. 44–63.

Daioglou, V. et al. (2012) Model projections for household energy use in developing countries, *Energy* 37, pp. 601-615.

International Energy Agency and the World Bank (2015) *Sustainable Energy for All 2015—Progress Toward Sustainable Energy*, World Bank, Washington, DC.

Kojima M., Bacon R., and Zhou X. (2011) *Who Uses Bottled Gas? Evidence from Households in Developing Countries,* Policy Research Working Paper 5731, World Bank.

Leach, M. and Oduro, R. (2015) Preliminary design and analysis of a proposed solar and battery electric cooking concept: costs and pricing, *Evidence on Demand*.

REN 21 (2015) *Renewables 2015, Global Status Report.*

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