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The Transfer of Energy Technologies in a Developing Country Context – Towards Improved Practice from Past Successes and Failures

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***Abstract*—**Technology transfer of renewable energy technologies is very often unsuccessful in the developing world. Aside from challenges that have social, economic, financial, institutional and environmental dimensions, technology transfer has generally been misunderstood, and largely seen as mere delivery of high tech equipment from developed to developing countries or within the developing world from R&D institutions to society. Technology transfer entails much more, including, but not limited to: entire systems and their component parts, know-how, goods and services, equipment, and organisational and managerial procedures. Means to facilitate the successful transfer of energy technologies, including the sharing of lessons are subsequently extremely important for developing countries as they grapple with increasing energy needs to sustain adequate economic growth and development. Improving the success of technology transfer is an ongoing process as more projects are implemented, new problems are encountered and new lessons are learnt. Renewable energy is also critical to improve the quality of lives of the majority of people in developing countries. In rural areas energy is primarily traditional biomass. The consumption activities typically occur in an inefficient manner, thus working against the notion of sustainable development. This paper explores the implementation of technology transfer in the developing world (sub-Saharan Africa). The focus is necessarily on RETs since most rural energy initiatives are RETs-based. Additionally, it aims to highlight some lessons drawn from the cited RE projects and identifies notable differences where energy technology transfer was judged to be successful. This is done through a literature review based on a selection of documented case studies which are judged against the definition provided for technology transfer. This paper also puts forth research recommendations that might contribute to improved technology transfer in the developing world.

Key findings of this paper include: Technology transfer cannot be complete without satisfying pre-conditions such as: affordability, maintenance (and associated plans), knowledge and skills transfer, appropriate know how, ownership and commitment, ability to adapt technology, sound business principles such as financial viability and sustainability, project management, relevance and many others. It is also shown that lessons are learnt in both successful and unsuccessful projects.

***Keywords*—**Technology transfer, technology management, renewable energy, sustainable development.

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I. Introduction

TECHNOLOGY transfer in Africa has often not had the desired impact despite globalization and international efforts at cooperation. In many instances, well designed technologies do not become broadly adopted, not because of inherent flaws but because there is no sustainable method of distribution, servicing and improving the technology [1]. Often, this may be attributable to the technologies, techniques and practices often not being absorbed successfully so that the ability of the recipient country to meet local needs is not improved. The use of renewable energy technologies (RET) has been hampered by various factors, including: their failure to reach commercialization; lack of financing mechanisms, often being dependent on donor funding; inadequate provision of technical assistance for training in maintenance; inappropriateness of the technology for the locales; and the lack of understanding of the limitations of such systems [2]. Lack of technology management plans and project management skills has also been detrimental to project success.

Technology transfer has generally been misunderstood and largely perceived as mere delivery of high tech equipment from developed to developing countries or within the developing world from R&D institutions to society. Technology transfer and technology diffusion are often used interchangeably. Technology transfer entails much more, including, but not limited to: entire systems and their component parts, 'know-how', goods and services, equipment, and organizational and managerial procedures. It is widely accepted that technology transfer is a complex process and that there is a need to find depth to its meaning. The private sector sees technology transfer in the context of 'joint ventures' while the receiving governments see it purely as technology implementation, thus there is a disjuncture in how technology transfer is perceived or understood [3].

Technology transfer involves both 'hard and soft' technology. Hard technology includes plant, machinery, and equipment, while soft technology includes training, know-how, and more efficient means of organizing the existing factors of production [3]. Technology transfer may take two routes: vertical technology transfer which excludes the sharing of intellectual property, and horizontal technology transfer, which includes the long-term sharing of intellectual property [4]. Largely, the narrow definition in terms of hard technology transfer has been adopted in developing countries and hard technology has subsequently overshadowed training, institutional capacity and infrastructure, all of which are pre-requisites for sustaining hard technology. Technology transfer can be an important means by which developing countries gain access to technologies that are new to them [5], and has an important role to contribute to sustainable development in Africa. As rightly observed by Science and Development Network, 2007, technology development must facilitate for newly acquired knowledge to be deeply assimilated and ultimately result in creative management, design engineering and innovation.

To illustrate the process of technology transfer in the developing world, a selected list of unrelated case studies from Zimbabwe, South Africa, Botswana and Kenya is reviewed. These case studies were selected because of the long experience with the implementation of diverse rural RETs in the case of Zimbabwe, the relatively unique experience with large community biogas digesters for water pumping in Botswana, the high success rate of the *Jiko* ceramic stoves in Kenya and the current aggressive push for the total electrification of South Africa. Case studies were rated against the definition of the various components of technology transfer.

II. Case Studies

A. Zimbabwe

Electrification levels in Zimbabwe relatively good recorded at around 40% of the population in 2005 [6]. However, alternative energy has been seen as an option to meet the energy needs of the poor. National government energy policy has focussed on promoting the introduction of efficient cook stoves to save energy; trials with various other RETs including solar photovoltaics (PVs), biogas digesters, crop waste briquetting and community woodlots development. Although the number of RETs projects was quite considerable, not all of them succeeded. Some of the projects and how they fared, including key learning points, are summarised in Table I.

TABLE I
List of Projects Implemented in Zimbabwe

Nature of project	Approximate number of units	Comments
Biogas	Over 200 units	By 1997 only c 15 operational. Lack of maintenance of infrastructure was the main problem
Solar PV	85 000	By 2002 only 60-80% were operational, the rest had maintenance and spares problems
Wood / coal Stoves	14 000; coal stoves <1%	By 1997 95% had been abandoned. Top down design and implementation
PV water pumping / mini micro hydro	15 sites nationwide	Locally trained maintenance staff helped the survival of this largely private initiative [7].
Gasification	About six units, 2 were government research trial.	Also successful as championed by private sector, entrepreneurs showed interest in establishing own plants
GEF Solar PV project 1993-1996 (Jointly funded Zimbabwe Government)	Project was expected to install 9000 solar lighting systems. project intended to enhance the commercial market for affordable domestic solar energy lighting systems and enable rural households to buy solar house systems	Project proponents and the beneficiaries' goals were divergent as the beneficiaries would have preferred broader application of the technology e.g. water pumping rather than just lighting [8].

Source: Adapted from [7]

Key Learning Points

- Some of the solar PV project beneficiaries were farmers and their payment of maintenance fees was linked to the ability to harvest and sell their produce and were therefore susceptible to weather conditions and erratic income patterns.
- The scattered nature of the facilities made them costly to maintain

- Establishing beneficiaries needs first and ensuring participation in the planning by all relevant stakeholders would help project success as indicated by the GEF solar project [8]
- Top down approaches as shown by the stove project do not enhance project success.

A majority of the case studies in Zimbabwe were unsuccessful projects. Technology transfer (and management) was generally not seen as an entire system. Component parts such as spares were not included as part of the planning. Soft technology issues were such as training and capacity building, affordability, maintenance, etc. were not addressed in a majority of the cases (see Table I). The financial viability and sustainability of the projects that did not succeed were also not well conceived. This follows the observation that projects which were run privately continue to operate successfully, for example, the gasification project and solar PV projects. This observation suggests that if a good business case is connected to a RET project, the project may have a better chance of success. Poor construction of rural household biogas digesters in Zimbabwe in the initial phases of the project coupled with poor maintenance by poorly trained users led to hardware falling into disuse [7]. Failure to consider local traditions during design of products is detrimental to the success of projects as indicated with the improved stove programme as the stoves were designed to work during the day when cooking was done in the evenings.

B. South Africa

1) Solar Electrification by the Concession Approach

The objective of this programme was to electrify 300 000 households in 5 years, divided into 50 000 households per concessionaire. Under this system the concessionaire was expected to use any technology they saw fit to deliver energy services at a fee to end users. Most opted for solar energy. There was a government subsidy attached to each connection (around 75% of the initial hardware). There were also monthly fees of around $7 to cover maintenance.

2) South African Solar Projects in rural South Africa: The Eskom-Shell Solar Home System Project in Eastern Cape and Limpopo provinces[1]

Eastern Cape

This project involved the installation of a pre-paid solar system with battery storage. The solar system used features four high efficiency fluorescent light bulbs and an outlet for black and white TV and radio. Local shops were used as outlets for buying pre-payment cards and local people were trained to install systems and do maintenance which enhanced job creation. About 6000 solar systems were installed by the end of March 2000. Measures to assess designs and check whether they were on target, or needed reviewing were put in place and these measures contributed to a reduction in costs of about 20%. This project had unique features for example, if a payment was not made, it could be disabled; monthly payments were collected and there was barcode identification for each customer to track performance. The project had anti-theft measures and was the first prepaid SHS in South Africa. Maintenance and component replacement were included in the cost. A total of 65 jobs and 185 power house sales outlets or local *spaza* shops were created through this project and development was the core founding principle behind this project. A similar project was launched in rural Limpopo Province.

There were recurrent issues and observations in the two concessions projects which are discussed henceforth. In both cases SHS beneficiaries tended to be wealthier households. In both beneficiaries appreciated lighting and entertainment (TV). However, problems in the two were also apparent. Lack of ownership was a source of discontent. There was not much skills transfer as beneficiaries could not even change their own lights. Use of SHS was somewhat punitive in the sense that ‘fee for service’ applied, even if there was a problem with the facility beneficiaries still had to pay. SHS users paid much more per month than did other facility users e.g on grid electricity users. SHS use was limited in its application and could only be used for lighting and did not meet expectations for cooking and the ability to use other appliances. Even then, only a minimal number (3) of lights could be used. These limitations perpetuated the need and dependency on other fuels for lighting resulting in further expenditure on fuel. It was also established upon scrutiny of the projects that the reach of SHS projects was limited to the relatively ‘wealthy’ of the poor as regular income was used as a criteria to provide the service. Subsequent reviews of the concessions projects indicates that Shell-Eskom repossessed a sizeable number of SHS units due to non-payment[2].

Key Learning Points

It is important that any off-grid energy solution adequately meets beneficiaries’ needs and expectations. It is also equally important that a holistic approach is followed in meeting the energy needs of rural people. Affordability of the system is another key consideration. Skills transfer also needs to be seriously considered, it is ludicrous that beneficiaries could not even do basic maintenance, e.g change bulbs. If a system is designed to be a solution for the poor a lot of things need to be considered, e.g appropriate (not punitive) cost recovery methods, selection means, etc.

3) Folovhodwe[3]

The project was intended to provide off-grid power in the form of PVs for 582 households. The project was meant to put the village on the power supply line and to ensure less dependence on fossil fuels. The Bavarian Government as well as the national Department for Minerals and Energy in South Africa were involved in the project. The system was intended to operate a high efficiency fluorescent light and small electrical appliances e.g. radio and a black and white TV. The pilot project cost R2.5 million. The 582 PV units were installed in 1998; by mid 2004, only 13 were operational.

[1]http:// www.erc.uct.ac.za

[2] Of the 6000 systems installed, 1400 were taken back (DRE Update in 9 countries)

[3] Based largely on the paper written by Bikam and Mulaudzi (2006)

There had been about 20 thefts and the remaining 549 were no longer operational. In its initial year of operation, the pilot project was able to deliver a constant supply of electricity, however, sustainability problems manifested. In 2002, there was a marked rise in the total breakdowns from 72 in 2000 to 3149 in 2002. Upon assessment of the project [9], the following was established:

- Cost of facility maintenance
  Fundamentals such as the need to pay for maintenance and the difference of PV systems from conventional on-grid electrification, were not very clear to the receivers of the technology. Maintenance finally stopped when the six trained technicians left due to poor pay. Spare parts had to be ordered from abroad, which also severely hampered the project resulting in long delays.
- Lack of maintenance skills on the part of recipients
  Project beneficiaries relied on the services of the technicians and could not perform any of the service tasks for themselves.
- Maintenance charges
  The maintenance fee increased from R100 to R135[4] and was burdensome to the already poor community. At project inception not all of them had been able to pay. The main fee was eventually reduced to R20, but few households paid resulting in a serious shortfall.
- Theft and vandalism of equipment
  The erection of the equipment on a 3m pole made it easy to steal or vandalize. However, this subsided after the equipment was placed on roofs.

Key Learning Points

Maintenance is a key issue in the successful implementation of RETs projects that must be considered carefully during project planning. Affordability needs to also be considered as a key factor of choice during the planning phase of projects. Additionally, capacity building is necessary to ensure that project beneficiaries are at least able to do basic maintenance themselves. Staffing is also a key element of project planning; six technicians could not have possibly been able to service the said number of units. Therefore, lack of user training and dependence on too few trained technicians proved to be major obstacles in project implementation. Local availability of spares is also important. Stakeholder engagement needs to be undertaken to ensure that project objectives, the product is understood, buy-in and support are obtained from the onset as well as beneficiaries expectations are managed throughout the project. Security of equipment is also critical.

The fact that out of 582 units installed at the start of the project only 13 were operational by 2004 is indicative of a project that failed. Hardware was provided and it is unclear whether technology management was in place. The procurement of spares does not seem to have been planned for. Equally, the transfer of skills was not included as only six technicians were trained without expanding the training component.

[4] 1 ZAR is equivalent to approximately 9 Euros or U$7

C. Botswana Biogas Project

Botswana used biogas water pumping using large digesters of up to 103 cubic meters during the 1980s. The first water pumping digester stationed at Diphawane depended on the collection of cow dung by those who used the water [10]. This was eventually abandoned as cow dung collection was erratic since contribution of cow dung was not linked to quantity of water fetched. The roles and responsibilities in the project had not been clearly spelt out from the onset. The second biogas water pump stationed at Mogwalale worked for the first two to three years; thereafter it was abandoned when the engine broke down. Another biogas water pump installed in Serowe was never used due to a shortage of cow dung. Others installed in South West Botswana did not succeed, e.g. one was made from drawings by a women's group and mistakes were made during construction and help was not accessible due to the remoteness of the sites.

Key Learning Points

What seems to have hampered the projects in Botswana was a lack of ownership and commitment on the part of the recipients. Other problems relate to the maintenance and training as part of soft technology. Effective technology management systems including quality control are important to ensure that technology works efficiently, building from memory and failure to use the right measurements did not bode well for the success of the projects.

The biogas projects in Botswana were also failures due to ill consideration of project components beyond simply providing hardware.

D. Kenyan Ceramic Stove (JIKO)

A well known success story is the introduction of a more efficient ceramic charcoal cooking stove, the *jiko*. About 780 000 stoves were disseminated in Kenya during 1995 [11]. Around 50% are urban homes and around 16% in rural homes. International and local development funds drove the project. The Kenyan jiko stove is hailed for its ability to reduce emissions of products of incomplete combustion which cause respiratory infection. It also reduces fuel use by 30-50% although there are variations based on quality, etc. There are over 200 businesses centred around the *jiko*'s manufacture. There are numerous role players in the dissemination of the *jiko*, e.g public and private sector organizations involved in aid, development, health and environmental conservation. The R&D process leading to the commercialization of the technology was seeded by international and local development funds and later a decision was made not to directly subsidize it although the designers and manufacturers were supported. To begin with the stoves were expensive at US$15 per unit which resulted in slow sales. However, with continued research and continual improvement, it was possible to increase competition, innovate and ultimately reduce the price to around US$1-3 depending on the size, design and quality. It is also possible to take back old stoves when the lining is destroyed and refurbish them for resale - a process which has found support in the informal sector economy [12].

Key Learning Points

Support to designers and manufacturers aided the success of the *jiko*. Less subsidization and more healthy market competition led to the introduction of much cheaper *jikos* in the end (from $15 to $1-3). The *jiko* used high quality fuel or charcoal, used a simple design with high energy efficiency thus improving indoor air quality for users.

The Kenyan *jiko* is a good example of a technology transfer project in the developing world context. The continually improved design was undertaken by the Kenyan people and issues such as local appropriateness, local acceptance, etc. were adequately addressed. The *jiko* technology has been implemented and adapted for use in a number of countries including Ethiopia, Malawi, Niger, Rwanda, Sudan and Uganda. In Kenya itself, a majority of the rural population uses wood and this has resulted in the *jiko* being adapted for use with wood, and this has involved the same organizations that worked on the jiko. Lessons have therefore been integrated from the charcoal and wood stoves resulting in great support for both programs. However, the example also shows that quality could be compromised with e.g the extension of the wholesale and retail network and the development of the informal economy around the stove making it difficult to control the quality of the product in the long run.

In the context of international technology transfer, the *jiko* example has important lessons. These include: the possibility of significant innovations in the technology arising from support for research both within developing nations and research collaborations; extended, stable program support is essential, but caution must be exercised not to foster dependency; and partnerships between institutional groups, including NGOs and international organizations involved in R&D promotion and training are also important in the dissemination of technology [12].

III. Conclusion and Recommendations

RETs are increasingly becoming relevant in sustainable development discourse in Africa. However, the growth and expansion of these will require increased technical know-how in developing countries including, but not limited to: capabilities to adapt, operate and maintain technologies to build local manufacturing industries. The above case studies have illustrated the need to have both soft and hard technology aspects in place. On top of this, all role players or stakeholders along the technology value chain need to play their part. Success is determined not on the RET option but on the framework in which it will be deployed, used and maintained.

The case studies indicate that there is a need to ensure good practice in energy technology transfer as demand for RE grows. Efforts need to be made to ensure a common understanding of technology transfer. Documenting and sharing of lessons is critical as part of technology management. The case studies also suggest that there are areas of research that need to be undertaken as indicated below:

Recommended Further Research to Improve Technology Transfer in Africa

- Research is needed to help understand technology transfer and organizational management systems in the energy sector to address the reasons for failure of technology transfer.
- Research is needed to help develop a business model that is appropriate for technology transfer in a developing world context, one that is scientifically based and is robust enough to promote effective technology transfer in the energy sector in the rural areas. This research would assist future planning and decision-making around energy renewable projects as well as improve existing projects through the lessons learnt for successful project implementation.

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