The Transfer of Energy Technology:
A Case Study of Hydropower in Lesotho

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Declaration

I declare that this half-dissertation is my own original work. It is being submitted in partial fulfillment of the requirements for the degree of Master of Science in Applied Science at the University of Cape Town. It has not been submitted before for any degree or examination at any university.

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ABSTRACT

This work investigates strategies for the transfer of energy technologies so as to develop the necessary capability for adapting and adopting such technologies in the recipient country using the transfer of hydropower technology to Lesotho as a case study. The work reviewed the literature on this subject as a background to the development of a technology transfer framework that formed the basis of the analysis. The framework was tested using the Muela hydropower project in Lesotho. Existing mini-hydropower projects in Lesotho were also reviewed to identify possible lessons from them regarding objective of this study.

The work shows that although some technical and operational skills were transferred during the life of the project, the skills for troubleshooting and product modification, which will greatly enhance the process of technology transfer, were not transferred. Policies were suggested to ensure that such skills are transferred in the future.

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List of Abbreviations and Acronyms

ADB	-	African Development Bank
AFREPREN	-	African Energy Policy Research Network
CDM	-	Clean Development Mechanism
CMA	-	Common Monetary Area
CRADAs	-	Cooperation of Research and Development Agreements
CTI	-	Climate Technology Initiatives
DBSA	-	Development Bank of Southern Africa
DOE	-	Department of Energy
EDF	-	Electricity Development Fund
EDI	-	Electricity Distribution Industry
EDRC	-	Energy Development and Research Centre
EIB	-	European Investment Bank
EIT	-	Economies in Transition
ESI	-	Electricity Supply Industry
ESKOM	-	Electricity Supply Commission, South Africa
ESTs	-	Environmentally Sound Technologies
ETSR	-	Energy Technology Status Report
FDI	-	Foreign Direct Investment
GDP	-	Gross Domestic Product
GEF	-	Global Environment Facility
GHG	-	Green House Gases
GNI	-	Gross National Income
GoL	-	Government of Lesotho
GWh	-	Giga Watt hours
GSJV	-	Gibbs Sogreah Joint Venture
IEA	-	International Energy Agency
IIASA	-	International Institute for Applied Systems Analysis
IPCC	-	Intergovernmental Panel on Climate Change
IPPs	-	Independent Power Producers
IPR	-	Intellectual Property Rights
ISO	-	International Standards Organisation
JI	-	Joint Implementation
JPTC	-	Joint Partnership Technical Commission
kV	-	Kilo Volts
KW	-	Kilo Watts
KWh	-	Kilo Watts hours
LDCs	-	Least Developed Countries
LEC	-	Lesotho Electricity Corporation
LEMP	-	Lesotho Energy Master Plan
LHDA	-	Lesotho Highlands Development Authority
LHWC	-	Lesotho Highlands Water Commission
LHWP	-	Lesotho Highlands Water Project
Masl	-	Meters Above Sea level
MCC	-	Muela Control Centre

MDBs	-	Multilateral Development Bank
MHP	-	Muela Hydropower Plant
MHPC	-	Muela Hydro Power Contractors
MW	-	Mega Watts
MWh	-	Mega Watts hours
NCC	-	National control Centre, Lesotho
NGO	-	Non-Governmental Organisation
NOSA	-	National Occupational Safety Association
NSI	-	National Systems of Innovation
NTTC	-	National Technology Transfer Centre,
ODA	-	Official Development Assistance
OECD	-	Organisation for Economic Cooperation and Development
R	-	Rands, South Africa
RD&D	-	Research, Development and Demonstration
SABS	-	South African Bureau of Standards
SACU	-	Southern African Customs Union
SADB	-	Southern African Development Bank
SADC	-	Southern African Development Community
SAPP	-	Southern African Power Pool
TCTA	-	Trans-Caledon Technical Authority
TNCs	-	Trans-national Companies
TWh	-	Tera Watt-hours
UNCTAD	-	United Nations Conference for Trade and Development
UNDP	-	United Nations Development Programme
UNEP	-	United Nations Environmental Programme
USDOA	-	United States Department of Agriculture
UNFCCC	-	United Nations Framework Convention for Climate Change
WEC	-	World Energy Council

CHAPTER 1

INTRODUCTION

1.1 The Background of Technology Transfer

The global trend in the developing and least developed countries is towards attainment of sustainable development by reducing the economic and technological gap between them and industrialised countries. The transfer of energy supply technologies from the developed and industrialised world is one of the approaches that can assist the least developed and developing countries to achieve this desire and their developmental aspirations. However, the success of such transfer process depends on many internal and external factors, and involves different actors. and the implementation method used.

Generally, technology transfer is seen as the diffusion of well proven and matured technologies from one location or organisation to another together with the embedded knowledge for installation, operation, maintenance and replication of the technology (Mertz et al., 2000; Davidson, 2002; Cray et al., 2002). Technology transfer includes both the tangible and intangible components, and the transfer process may occur either among the developed countries or between developed and the developing countries as well as those countries referred as economies in transition (EITs). In addition, the process can happen between international private sector and private sector with public sector within and in different countries.

The process of technology transfer includes learning, utilising and replicating of technology as well as capacity to identify and adapt the technology to local conditions and integrating it with available and indigenous resources (Dixon, 1999; Kathuria, 2002). The development of technology involves engineering designs, procurement, construction or installation, and lastly operation and maintenance (Kathuria, 2002; Audus, 2000; Cray et al., 2002; Bennett et al., 2002). The basis for the definition of technology transfer depends on the nature and the discipline of research or type of technology, and according to the purpose of the transfer process. The socio-political as well as technical and economic factors of the technology recipient country also have influence on the mode or mechanism of transferring technology, as the process may happen either from one country to another or from one firm to another (Bozeman, 2000; Pack, 2000; UNCTAD, 2001; Cray et al., 2002).

The success of a transfer process is difficult to determine but different stakeholders such as the United Nations Development Programme (UNDP) have proposed several suggestions to determine success. They described successful transfer of technology as when the recipient is able to assess, choose and adapt technology to the local conditions, integrate it to available technologies and utilise indigenous resources in a sustainable way (UNDP, 1999). This description is important because the technology recipient must also be able to replicate and transfer the original technology with improvements in order to attain sustainability in technology development. An important attribute of technology that also affects the transfer process is its maturity. It is essential to transfer matured technologies to countries with limited technological capability, as they are incapable to bear the risks that are associated with immature technologies. Maturity of a technology involves testing, approval and verification that the technology is appropriate, adaptable, trouble free and satisfies all quality control standards as well as environmental friendliness (California Energy Commission, 1997; Lennon et al., 1999; Bennett et al., 2002). The other characteristics of maturity are affordability accessibility, availability, acceptability and potential for replication. Also, in many cases, it is desirable that the technology be up-to-date or state-of-the-art.

Several aspects are involved in dealing with technology transfer. Three important ones that have direct relevance to the technology recipients are capacity building, an enabling environment for transfer, and the transfer mechanisms. Competent human resources with skills such as technical expertise, business management and regulation are highly essential at all stages of technology transfer. An enabling environment includes a stable governing structure and effective regulatory frameworks, proper management and institutional arrangements, as well as adequate techno-economic policies (Audus, 2000; Cray at al., 2002; Marshall et al., 2002; Lamech et al., 2003). The mechanism of transfer determines the mode of transfer that may be appropriate to either import, acquire or transfer the hardware or software.

Major problems normally encountered by technology recipients are receiving failed or near obsolete technologies mainly because of their poor capability to assess and select the appropriate technology. This transfer process is usually referred to as technology dumping. In most cases, technology dumping has negative consequences on the recipient.

1.2 The Opportunities for Technology Transfer in Lesotho

Technology transfer present major opportunities to least developed countries such as Lesotho that receive significant foreign assistance. One such assistance may be in the form of Official Development Assistance (ODA) from the developed countries. As an example, the energy sector of Lesotho received grants from the developed countries for the construction and installation of four mini hydropower plants (Kanetsi, 2002). In addition, foreign investors provided grants for sub-stations, transmission lines and the distribution networks especially in the urban areas. Since the late 1980s, however, assistance in the form of ODA has been decreasing and at the same time Lesotho has not been a good destination for neither major foreign direct investment (FDI), commercial lending nor equity investments. The country is also experiencing major fluctuations in the exchange rate of its national currency (Central Bank of Lesotho, 2003). Hence, the country can benefit technically from bilateral agreements provided there is necessary policy environment.

1.3 The Electricity Supply Industry of Lesotho

A brief overview of the electricity supply industry (ESI) in Lesotho is included here because it pertains to the objective of this study and so will provide a background to the objectives that are enumerated below. The ESI in Lesotho, as in other developing countries is rapidly changing but it is far from satisfying the national electrical energy demand. This situation will affect the technologies used for generation, transmission and distribution of electricity to end-users in both the short and long term. Further, the international obligations and commitments by Lesotho to international agreements such as the promotion of sustainable development and the reduction of the green house gases (GHG) emissions will influence the technologies used in its energy sector. The agreements will also indirectly influence the international funding sources to the transfer of energy technology (Rahaman, 2003). The ultimate goal for the ESI in Lesotho is to acquire power production and related technologies that will improve the sustainable development of the country. The anticipated goal will also be to reduce reliance on external countries for both technical skills and electricity production, while addressing the environmental concerns of the country.

The electricity supply infrastructure of Lesotho is under the responsibility of the national power utility, Lesotho Electricity Corporation (LEC). It includes some small-scale hydropower plants, transmission lines with maximum of 132 kV and a distribution network that is supplying less than ten percent of total households in Lesotho. In addition, there is Muela Hydropower plant that generates approximately 90 percent of current electricity used while Eskom, the power utility of South Africa supplies the rest of the power utilised.

Improving the ESI infrastructure in the country will require not only significant investments to develop its small and large hydropower potential but also the associated technologies, and highly competent manpower with the required technical skills and knowledge. These skills are not always in sufficient quantities in Lesotho. Therefore, transfer of such skills is necessary for electricity generation and use in the country. The specific essential skills needed include project management, general engineering, planning, construction, and commissioning of energy technologies. In addition, overall engineering management including operations and maintenance of technology is also important as that will improve its technical performance and effectiveness (Wild, 1995; Audus, 2000; Kathuria, 2002).

In general, Lesotho as a least developed country can create an enabling environment that attracts investments from environmentally concerned countries and their respective companies. The enabling environment for technology transfer includes security of markets, proper institutional set-up and regulations, and absorptive capacity (Davidson, 2002; Bennett et al., 2002; Lamech et al., 2003). This will also lead to an opportunity to leapfrog to higher stages of development on a more sustainable development path. A crucial step for Lesotho is to identify and realise promising opportunities offered by developed countries and transactional corporations (TNCs). In addition, they may need to develop their negotiating skills with multinational financiers in order to benefit from technology imports needed for their infrastructure development.

1.4 Objectives of the Study

The objective of the study is to investigate strategies for transferring energy technologies using the Muela hydropower plant implemented under the bi-national Lesotho Highlands Water Project (LHWP) as a case study. The study will also determine whether the procedures for planning and implementation of the Muela hydropower followed the principles and guidelines of a suggested theoretical framework for technology transfer. The focus is on identifying the areas of effectiveness and successful transfer of technologies with the hope of suggesting improvements in the future.

Hence, the main objectives of the study are as follows:

- To collect appropriate data in Lesotho that will assist to carry out the main objective of study.
- To develop and adopt a framework for technology transfer and determine its applicability on the case study mentioned.
- To investigate the possible technical, economic and organisational options and suggests strategies for the improvement of acquisition, maintenance and replication of energy technologies.
- To investigate the challenges and benefits of maintaining energy supply technologies using the case of hydropower plant in Lesotho.
- To formulate policy recommendations that will address the weakness identified by the analysis.

1.5 Methodology of Work

The adopted methodology is aiming to accomplish the objectives outlined. The exercise included gathering of information from the literature and from field visits that include interviews with relevant stakeholders. The research tasks undertaken were as follows:

- A critical literature review of technology transfer on power generation with particular emphasis to the least developed countries that are financially and technically disadvantaged.
- Study of the essential activities of the technology transfer process including theoretical technology transfer models, lifecycle flow-charts, and frameworks
- Study of the power sector in Lesotho with emphasis on the existing mini hydropower plants.
- Review participation of people from Lesotho in planning, design, construction, commissioning, operation and maintenance of power production technologies.
- Identify institutional linkages for creation of self-reliance on power generation by providing training requirements for the relevant and above-mentioned skills.
- Investigating and examining whether the planning, engineering and procurement of Muela hydropower technology as case study are conducive and complying with the principles of the framework for technology transfer and make policy suggestions.

1.6 The Outline of the Report

The first chapter discusses the introduction of the study. It also outlines the brief background of the case study as well as the overall objectives of the study. In addition, the chapter provides the methodology and the outline of the report.

Chapter 2 discusses the literature on the process and elements of technology transfer. The chapter also discusses the barriers to technology as well as the implication of technology transfer pertinent to Lesotho. The chapter further reviews the literature on technology transfer as the topic indicates.

Chapter 3 discusses the different technology transfer models, lifecycle flow-charts, and conceptual frameworks. The chapter also looks into the development of the integrated framework for technology transfer, which in turn serves as the guidelines for the analysis that followed. It includes the description of different stages and activities of the framework applied in the case study.

Then Chapter 4 describes the power-generating sector of Lesotho. The emphasis is mainly on the power generation sector and the predominantly dominating mini-hydropower technologies as they provide necessary information regarding the objectives of the study..

Therefore, Chapter 5 presents the data and information collected on a case study of Muela hydropower technology. The data collection also includes the historical background and the project stages of Muela hydropower station. The chapter also discusses the essential elements for selection of hydropower technologies. The data collection follows the guideline questions drawn according to the stages of integrated framework for technology transfer.

Chapter 6 discusses the major findings and analysis of the case study using the framework adopted in Chapter 3 as guideline. The chapter also outlines analysis of the effectiveness and the barriers incurred during the implementation process.

Lastly, Chapter 7 makes some policy recommendations and draws conclusions of the study. The emphasis of conclusions will consider the theory of technology transfer mechanism, the technology of the case study and the applicability of the framework to be developed. The document also includes list of references as well as appendices for additional information.

CHAPTER 2

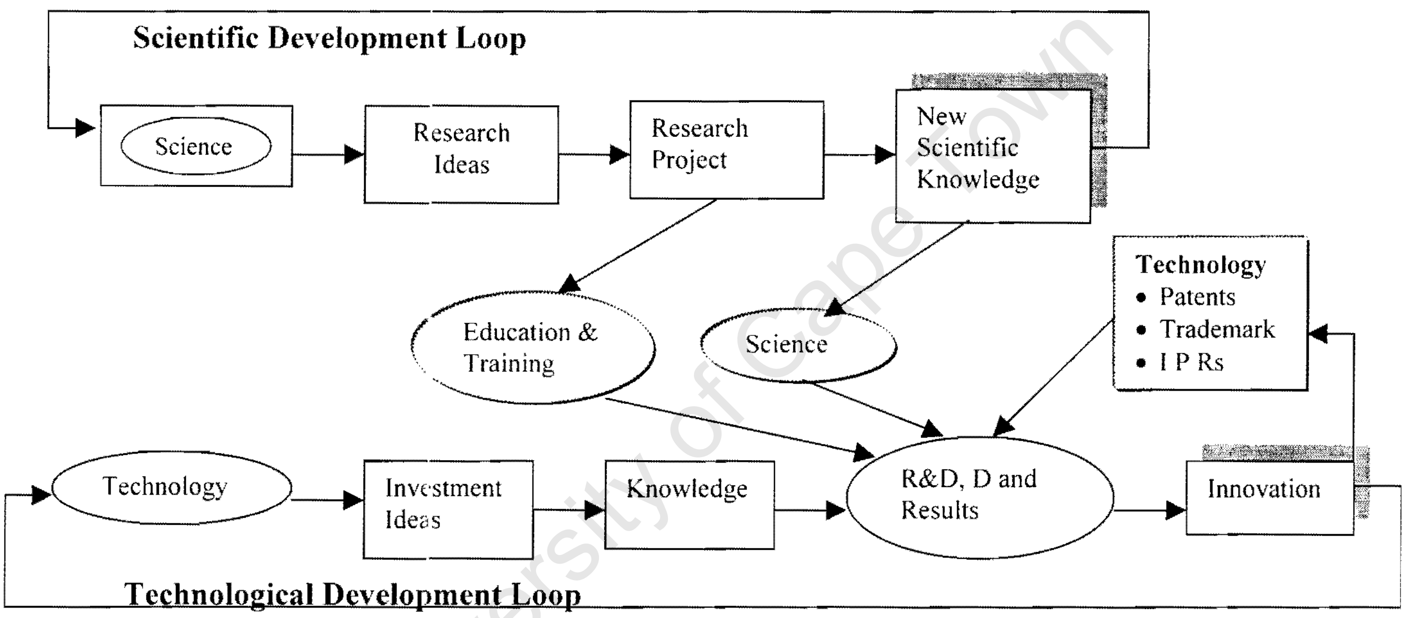
LITERATURE REVIEW ON TECHNOLOGY TRANSFER PROCESS

2.1 Introduction

In general, there is a strong correlation between science and technology as well as the transfer of knowledge and skills associated with both of them. The aim of this chapter is to review pertaining literature applicable to the dissemination of the scientific and technological knowledge as they concern the objective of this study. As a prelude to this review, the section gives few fundamental differences between science and technology, as that will assist in understanding the literature on science and technology dissemination.

Usually, science is universal and progresses to achieve academic and research acknowledgement, while technology may be 'local' or 'cultural' and it develops in accordance with the level of the economy and it is normally demand driven (Trinidade, 2002). Building of capacities in science and technology requires going through inter-linked stages of development which may not be linear because such linkage depends on the policy environment and the nature of the technology (Brundenius, 1993). Figure 2.1 illustrates the relationship between science and technology.

Figure 2.1: Science and Technology Loop



Source: Trindade 2002.

Figure 2.1 primarily demonstrates that Science and technology develop in parallel and merge at one end to form knowledge that may result into innovation of advanced technology. The science loop starts when the level of knowledge is low. Then it develops to reach the new scientific knowledge and eventually it may acquire an economic value. In addition, the structure shows that new scientific knowledge and technology innovations feed back into science and technology loops respectively.

In the case of the technology development loop, the level of the economy determines the technology requirement. Thereafter, the scientific education and training assists to convert the necessary ideas into knowledge. Then the technological and new scientific knowledge lead to research, development and demonstration (RD&D) as well as to the compilation of ultimate results. Subsequently, the obtained results lead to innovations and applications of technology. Similarly, the technological changes and technology transfer through trading protection mechanisms such as intellectual property rights, trademarks and patents rights feed technology into the scientific and technological pool of research and development (Trindade, 2002). The approval and recognition trading mechanisms stimulate the technology transfer process and enables the recipient to access and acquire technology from the suppliers.

2.2 Technology and Technology Transfer

In order to understand the whole process of transfer, it is important to define technology and technology transfer separately. In general, technology is either a 'hard' or a 'soft' object which can be physical equipment, machinery or technical knowledge. Technology transfer is the process of diffusion and acquisition of a physical object or technical knowledge. The section describes the characteristics of technology as well as the elements and stages of technology transfer.

2.2.1 Definition of Technology

The *Longman Dictionary of Contemporary English (1990)* defines technology as "branch of knowledge dealing with scientific and industrial methods and their practical uses in industry and practical science". Similarly, technology refers to application of knowledge for practical purposes such as engineering designs to convert potential energy and kinetic energy such as that in water into useful electricity. Technology is a piece of information, technique or product that is applicable to perform certain service. In addition, technology can take a form of a commodity, knowledge as well as socio-economic activity (Dixon, 1999). It further includes knowledge about complex applications and operations that are not easily transferable (Radosevic, 1999). On the other hand, technology is a systematic knowledge utilised for manufacturing of product for application in a certain process or rendering of a service (UNCTAD, 2001).

The ultimate users of technology have to know the achievements and limitations of specific technology as well as its characteristics such as flexibility, substitutability, reversibility, and adaptability (Davidson, 2000). The development of technology becomes more successful when the recipient can use it commercially. The criterion used to define and express the development of technology determines its maturity, existence of suppliers and its costs (California Energy Commission, 1997).

It is advisable that technology should always reach maturity phase of development before entering the market. Initially, it has to be scientifically feasible by showing compliance with the known physical laws. Secondly, it has to be technically feasible which verifies and confirms the scientific principles used towards the proposed concept. Technical feasibility includes the laboratory experiments that test the concept, general design and indicates whether the required materials are available to allow application of the proposed concept. The third phase is engineering feasibility whereby the designs demonstrate proposed technology in three-dimensional models. The demonstrated model can range from one tenth to a half of the full system. The design should be simple such that the end-user can use the technology without referring to the manufacturer. Lastly, a product has to pass the commercial demonstration phase. This phase involves the interaction of the end-user and the producer (California Energy Commission, 1997).

2.2.2 Technology Transfer

Technology transfer is a process that involves the transfer and acquisition of both tangibles and intangible technologies from one location to another (Bozeman, 2000; Mertz et al., 2000; Cray et al, 2002). In addition, technology transfer can be a process involving the flow of technical knowledge. experience and equipment for mitigating and adapting to climate change (Mertz et al., 2000). The soft or intangible technologies are capacity building, information networks, training and research. Conversely, "hard technologies include equipment and products to control, reduce or prevent emissions of greenhouse gases within the energy sector and other sectors" (Davidson, 2000). The transfer process includes transfer of expertise, facilities with the objective of improving them and getting to the stage of full commercialisation. Moreover, technology transfer process is a means of disseminating the commercial technology (UNCTAD, 2001; USDOA Graduate School, 2001). Technology transfer involves essential activities in the process of development starting with scientific and R&D discoveries, evaluation, acquisition, adaptation and implementation (Cray et al., 2002). In addition, it includes transfer of understanding, knowledge, utilisation and replication of technology.

Normally, the goals for transfer of energy technologies are to achieve many development goals such as job creation, reduction of energy costs, promoting self-reliance, sustaining economic growth, protection and enhancement of the environment (Mertz et al., 2000). Some technologies may be climate friendly and responsive while others can be hazardous to the environment. Therefore, selection of technology to satisfy these factors is important at early stage of technology transfer collaboration.

Technology transfer involves several stakeholders and intermediaries such as special government agencies, energy service companies, university liaison departments and electric power utilities. The process also incorporates the cross-national organisations, transnational corporations (TNCs), private sector entities, financial institutions, non-governmental organisations (NGOs) as well as research and education institutions (Mertz et al., 2000; UNCTAD, 2001). Technology transfer may occur among and across the developed countries, developing countries, and those with economies in transition (EITs) as well as in the least developed countries (LDCs). Similarly, the technology transfer process takes place between one company and another or from the industry to the consumers or subsidiary companies through joint ventures and licensing mechanism (Kathuria, 2002, Bozeman, 2000; Cray et al, 2002).

Internationally, the Northern Hemisphere based companies dominate technology transfer process, as suppliers of technologies while the Southern Hemisphere based companies are recipients, thus creating the common thinking about North-South transactions in technology transfer. However, technology transfer may happen from South-North and South-South as it happens in prepayment metering technologies from South Africa (Lennon et al., 1999). The situation indicates that the developing countries, EITs and new industrialised countries can play an important role in supplying technologies to both the developed countries and the LDCs or be partners for technology transfer projects. Other important parameter is for the supplier to know the requirements and technological needs of the recipient. Therefore, the entire process requires learning by both the supplier and the recipient of technologies irrespective of their economic status and the priorities.

2.3 The Barriers to Technology Transfer

The identified barriers to technology transfer vary from socio-economic factors to actual technical factors. The main barriers are as shown on Table 2.1

Table 2.1: Key Barriers to Technology Transfer

Institutional - The insufficient legal and regulatory bodies. These also influence the costs of transfer and success of technical understanding by the technology supplier. Overlapping responsibilities and poor integration to avoid duplication. Uncertainties of ownership, lack of intellectual property rights (IPR) protection, no incentives for sharing ideas, trademarks, and patents licensing agreement.
Political - Government and political interference can cause bureaucracy and instability.
Technological - Lack of infrastructure, absence of technical standards and specifications and less technical capability and expertise add to the technological barriers. These increase the costs of pre-engineering negotiations. Lack of skills to assess technology needs available experience within the developed countries and strategies for implementation.
Economic and Financial - Poor macro-economic conditions, discriminatory and non-transparent markets, instability, substantial tariff barriers and inappropriate subsidies. Limited access to capital, prejudice of financing mechanism towards traditional large-scale projects, and influence on technology choice in favour of conventional technologies as well as high risks for foreign investors.
Information - Inaccessibility to technical and financial information and resources, lack of specific information dissemination, and lack of information for consumers at initial stage.
Cultural - Recipient end user preferences, social biases and logistics, environmental and social costs cannot be fully internalised
Participation and Consultation - Lack of local participation and inadequate information regarding the needs and preferences of the recipients.
RD&D - Government may found funding problematic and difficult. Private firms also cannot support RD &D because they cannot benefit fully. In addition, there are uncertainties of cost reduction from RD&D results. The activities can be costly due to technological risks and high capital costs for exchanges of RD&D personnel. Low level of R&D capacity in the recipient country also increases the barrier.

Sources: Mertz et al., 2000; UNDP, 2000; Davidson et al., 2002; World Bank, 2003.

The following activities can help to eliminate some of the mentioned barriers above through:

- Building and empowering local skills by sharing information and strengthening the technical capacity of the labour force
- Encouraging and engaging the private sector participation in the process by creating a non-preferential and non-discriminatory business environment and allocating some incentives for environmentally sound technologies
- Application of development assistance approach by stimulating the market and improving effectiveness, efficiency and co-ordination within the government
- Developing innovative financing by pooling the resources in a manner that is equitable and by sharing possible risks.
- Direct public funding, tax incentives for collaborative RD &D
- Direct national support for local and international demonstration projects by provision of low interests and guaranteed loans.
- Creation of competitive but regulated market transformation
- Phasing out of well established non-renewable technologies and green labelling renewable technologies,

- Award concessions licences towards specific technologies and market (UNDP, 2000).

Moreover, the recipient must maintain stability, enforcement of laws and improving the responsiveness to the needs of the investors (Lamech et al., 2003).

2.4 Analysis of Literature on Technology Transfer Approaches

Most of existing literature on international technology transfer tends to elaborate the processes between the private sectors in two different countries. Literature also discusses national or internal technology transfer from company to another and from the research and academic institutions to the industrial sectors especially in the developed countries such as USA (US National Technology Transfer Centre (NTTC), 2003). The literature also shows that international technology transfer discussions emanated from the efforts and studies on Official Development Assistance (ODA), Foreign Direct Investments (FDI) projects and transnational corporations (TNCs) investments as well as multinational enterprises on commercial lending and equity investments (Mertz et al., 2000; UNCTAD, 2001; Cray et al 2002). The discussed strategies emphasised that the technology transfer mechanisms are subject to other factors such as the level of economic development of the recipient country and priorities of the technology supplier as well as the interests of the concerned investors.

The available information indicates technology transfer is not only about the imports and about exports of technological equipment and expertise of its operations. However, the process is broad and encompasses all the essential components that are necessary before, during and after transfer process such as ability to undertake assessment of the needs, capability to utilise technology and replication. The literature emphasises that technology transfer can take any form starting with the knowledge about the equipment and machinery. It also includes knowledge of selecting, optimising and adapting technology to the local environmental conditions and the capability of expanding the output of the machinery above the designed levels (Dixon, 1999; Davidson, 2002; Kathuria, 2002). In addition, technology can be intangibles and soft aspects including technical knowledge, blueprints, engineering designs, processes of operations as well as research and development results (Dixon, 1999; Bozeman, 2000). Moreover, technology can take a form of economic and development infrastructures as in the case of energy technologies such as hydropower systems.

The literature discussed different approaches of technology transfer starting with direct way of purchasing technology from either a local company or international companies. The second most important approach discussed is capacity building and training. Training can take different strategies such as technical assistance, personnel exchange, operations and maintenance enhancement as discussed. However, training has to be strategic and address the needs with time and space. In power sector, the important aspects that need consideration are engineering, installation, testing, operations, maintenance and troubleshooting (Nissen et al., 2003).

Training also depends on the availability of the science and technical infrastructure in a recipient organisation or country. Training and capacity building are highly essential in all the least developed countries (Bennett, et al., 2002). Training will encourage the science and technical (S&T) infrastructure, which acts as one of the determining factor of technology transfer. Training is essential in all the elements and stages of technology transfer such as needs assessment, technology selection, technology adaptation, replication as well as technology development and commercialisation.

Appropriate training in any form will enhance the LDCs to attain development with current technological trends (IIASA, 2000). Therefore, the LDCs must seek technical assistance and personnel exchanges as a means of acquiring technical knowledge in a faster and cost-effective way, but it requires commitment and ability to learn. However, training has to be proactive and intensive so that the recipient will not only be able to operate machinery but include capability for maintenance, diagnosing problems and troubleshooting. It is evident that the modern high-tech machinery and equipment have built-in protection systems but the operators must be eligible to undertake such actions independently as well.

The third approach of technology transfer in the literature discussed is licensing. It enable the recipient to utilise certain technology, to produce similar technologies to the parent company or supplier, or license permission to use similar processes and trade name or brands to that of the supplier of license. The process also includes legal issues such as intellectual patents right (IPRs), trademarks and necessary technical standards. Moreover, the licensing model is normally prominent where the interests of the technology suppliers are mainly toward the market within the recipient country. On the other hand, the recipient company intends to get faster means of owning business under a well-established trade name (Cicmil et al., 2002; UNCTAD, 2001; Cray et al 2002).

The licensing approach can take several forms, but the most common is through subcontractors. The subcontractor licensing occur when the technology recipient get into agreement with the supplier such as purchasing of certain complementary parts and using them according to the specifications of the technology supplier. The subcontractor licensing mechanism allows the recipient to acquire technical expertise and technical assistance on technology selection, operations as well as quality management.

However, licensing approach in general is rather costly and sometimes it is not advantageous to least developing countries as it limits the capability of research and development. In licensing approach the supplier sometimes can be very restrictive and delay the whole process of technology transfer as required due to more emphasis on protection of intellectual property rights (IPR) and patent rights. It also requires high level of management to maintain the same standards of the technology supplier and the conditions of license (Maskus 2000; Cicmil et al., 2002). Similarly, the favourable and acceptable government policies, local capabilities and the availability of science and technology infrastructure can give a technology supplier an assurance to invest in LDCs (Cray et al., 2002). This model of transfer also rely on the decisions from the foreign parent company or technology supplier and technology transfer can also be limited to certain areas of technological systems. The process is also subject to good relationship between the supplier and recipient as well as the government policies and local capabilities that can be subcontractors (Maskus et al., 2000, Cicmil et al., 2002).

The prominent aspect that emanates from the literature on technology transfer through licensing approach is high costs of getting licenses, the availability of science and technical infrastructure and restrictions of working under control of foreign licensing as technology supplier. On the other hand, the supplier may be restrictive as mentioned or even stop licensing contracts when realising the market is not conducive. Therefore, the approach does not encourage freedom to develop technology but only allow it to happen in accordance with the licence specifications, conditions and approval.

Another approach is collaborative research and development (R&D) which requires high scientific and technical infrastructure and capital resources. The effectiveness of R&D in the least developed countries is indecisive, as the demand of funding, opportunity costs, science and technical human capital and infrastructure would not guarantee such endeavours. Collaborative R&D has high capital and operational costs. In some cases, vulnerable LDCs can easily receive failed and near obsolete technologies and environmentally unfriend y scientific discoveries and innovations.

Information support is a soft or intangible technology that includes blueprints, designs, formulae, reading materials and others (Mertz et al., 2000). It is also important as it links other means of technology transfer such as research and development from different organisations. Similarly, information support is another cheaper approach that can be essential to transfer technical knowledge from the highly developed countries to the least developed countries. Information support can be irrelevant to the needs and requirements of the recipient. In a sim lar vein, poor strategy of information dissemination can cause confusion and misunderstanding. Recipient LDCs are vulnerable to accept anything on offer and can not make strategic selection without information support. In addition, information can mislead LDCs to purchase, import or get into joint ventures of high capital and technology intensive technologies such as fuel cells that are not necessarily beneficial. However, relevant information support is another area where the LDCs can benefit.

Institutional support is another approach that is more relevant to the LDCs because it is one of the essential components for them to build their capability. Institutional support as discussed in the literature can be scientific and technical infrastructure including laboratories to undertake any research and development activities. However, institutional support sometimes raises the question of ownership between the supplier and recipient (Cray et al., 2002). Institutional support mechanisms can be managerial systems, the legal systems to ensure protection of IPRs or regulatory mechanisms to ensure that technologies operate under fair market environment. Institutional support is also applicable and essential to LDCs, as the mechanism does not have high capital and preconditions embedded on it. The literature further indicates the code of practice agreed by the United Nations and its subsidiary organisations, encourages the technology supplier firms, transnational corporations (TNCs) and the developed countries to invest on institutional support in the LDCs. Investment is another means of enhancing sustainable development and adaptation of environmentally sound technologies (UNFCCC, 1997; Mertz et al., 2000; UNCTAD, 2001).

Literature also mentioned joint venture as another model for technology transfer. Joint ventures include creation of separate entity to address the interests and needs of the two or more parents companies, which will share profits in a basis of equity exposure of the parent partners or companies. Some companies opt for joint ventures when the resources are insufficient to cater for the technological costs and investments. The recipient and supplier of technology normally have different priorities in the process as mentioned. The priorities of the donors may be in research and development investments, production, marketing and sales (Cray et al., 2002). On the other hand, the interests of the technology suppliers are on markets and intellectual property rights. In a case where the stakeholders are governments especially of the LDCs, the technology recipient priorities are on development and fulfilment of the technological needs. In some instances, the investor, donors and the multilateral banks also focus on development goals (Mertz et al., 2000; Bozeman, 2000; Davidson et al., 2002).

Therefore, two entities can get into joint venture with different interests and benefits prospects. Joint venture is another mechanism of technology transfer which the LDCs can utilise by identifying the opportunities that are suitable for foreign investors and local needs. However, in order to identify such recipient technological needs and the prospects of the markets for investors, the recipient countries require sufficient training to assess such technological needs.

The different technology transfer mechanisms also differ in accordance with the economic status of the partners involved and whether they are private or public. The motivation and expectation of the recipient as well as the priorities of the technology supply also influence the mechanisms. Table 2.2 illustrates the summary of the mechanisms of technology transfer together with the factors that influence them. The table also indicates the factors that inhibit the diffusion of technology from different sectors.

Table 2.2: Factors of different technology transfer mechanisms

Participants in Technology Transfer	**Motivation to the Recipient LDCs**	**The decisions that Encourage or inhibit Technology Transfer**	**The Approaches that are Likely to be Implemented**
Governments in LDCs and in developing countries	• Development goals • Energy supply • Job creation • Infrastructure development • Environment goals	• Taxation policies including import policies • Science and technical human capacity • Institutional regulations, • Foreign direct investment policies	• Direct purchasing • Joint ventures • Turnkey contracts • Information support through technical tours, conferences, trade shows, symposia • Education and training • Foreign direct investment
Private sector, TNCs, national or local micro enterprises	• Profit and return on investments, • Market exploration • Opportunity costs	• Technology R&D, and selection • Commercialisation and marketing decisions • Capital investment • Skills and development capabilities • Choice of technology approach	• Licensing agreements, subcontracting, • Foreign direct investments, • Joint ventures
Donors, multilateral banks, Global Environmental Fund (GEF), bilateral aid agencies	• Development goals • Return on investment • Environment goals	• Technology and project selection criteria • Procurement requirements • Technical assistance design and delivery	• Development lending • Development aid and • Grant financing
International Institutions, OECD, UNCSD	• Policy framework • Development goals • ROIs • Environment goals	• Policy and technology focus • Selection of participants to forums • Modes of information dissemination	• Grants financing • Foreign direct Investments • Development lending
Academia and R&D Centres	• Basic knowledge • Applied research • Transfer of technical know-how	• Decision and government position on technology transfer, • Choice of approach to technology transfer	• Collaborative R&D, • Information support through conferences, symposia, results, workshops, exhibitions

Sources: Mertz et al., 2000; Maskus et al., 2000

2.5 The Implications of Technology Transfer for Lesotho

One of the major constraints of development confronting the least developed countries is high unemployment rate. In Lesotho and other least developed countries in sub-Sahara Africa, unemployment is above 30 percent (World Bank, 2003). Therefore, job creation is one of the important reasons that will increase the demand for technology transfer especially for infrastructure development. Therefore, the sectors that are likely to benefit are those that are primarily labour intensive like the textile industries as the governments normally prioritise them as the areas that need technology transfer. However, the international trend is moving towards extremely high capital and technology intensive operations with precisely high productivity and little unskilled labour requirements.

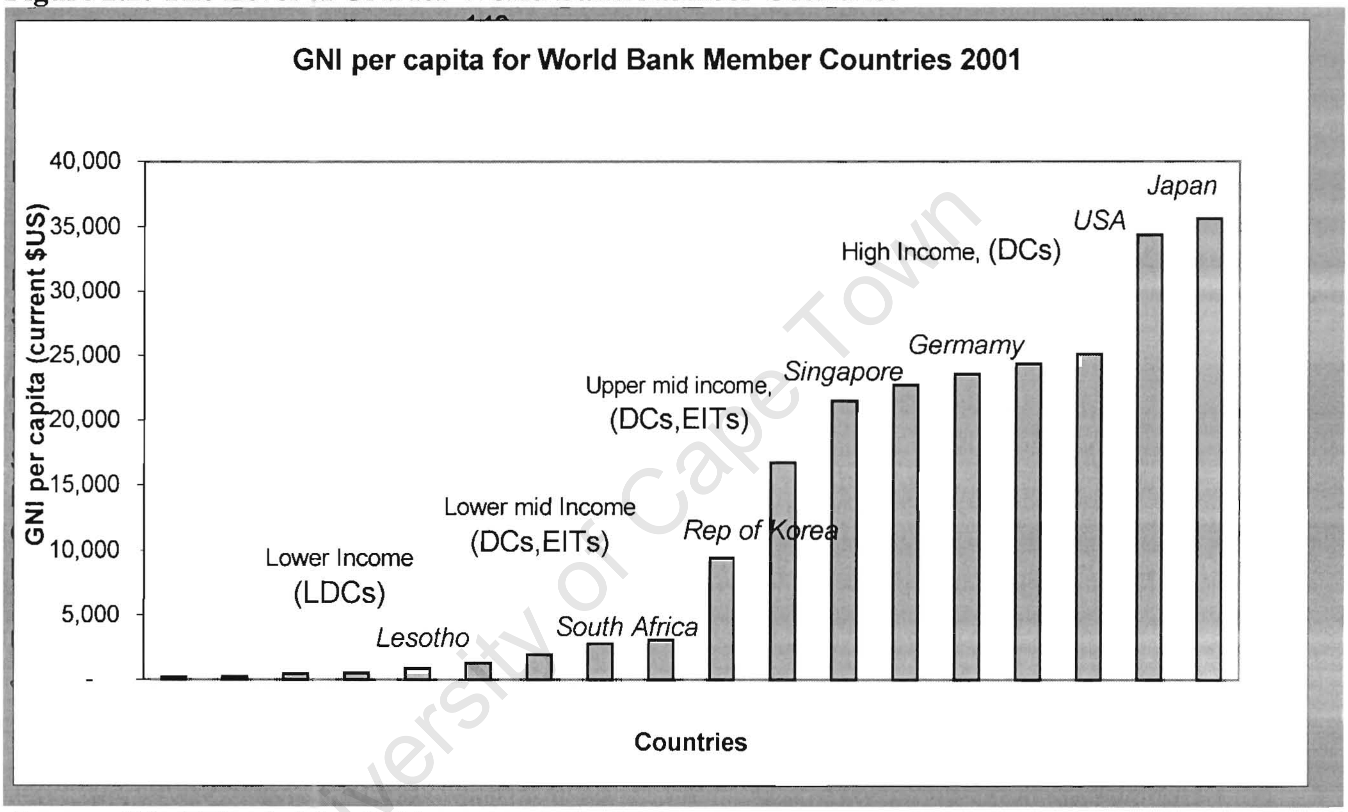
The literature discussion is not sufficient on the technology transfer process that is bi-national. Thus, there are not sufficient publications on cases where the transfer of technology happens in between the two governments. The literature is also not enough on cases where transfer of technology occur between one company in developing or developed to a government utility or department in a least developed country such as Lesotho. The mentioned factors indicate explicitly that technology transfer process involves costs and risks. The literature states that the mechanisms of technology transfer such as licensing or joint venture the shared risks are in a way of equity of the parent companies or partners (Cray et al., 2002). Therefore, in the case of a least developed country, the only entity that can be involved in negotiations and agreements of technology transfer normally is the government departments with technical orientation.

On the other hand, it is evident from the literature that the indicators that accelerate success of technology transfer include the level of industrialisation, gross national income (GNI), science and technical infrastructure. These indicators are also instrumental to qualify the country to be among as the least developed or developing, EITs or developed countries category. Similarly, the size of technology, its value, markets and the risks involved also determine whether the commercial and private sector can participate in transfer process or not. The governments of the LDCs including Lesotho can play a vital part of technology transfer especially where scientific and technical human capital and industrialisation level is low. However, in some countries the governments may restrict the diffusion of technology through policies that are not favourable for sustainability of technologies and the investors. The governments can discourage technology transfer by imposing management, appointing board representations in ambiguous way, making decision upon the quantity, quality and time of technology. The country may eliminate these barriers by eradicating political instability and interference in order to give assurance for technology suppliers (Bozeman, 2000; Cray et al., 2002; Lamech et al., 2003).

The LDCs are far from industrialisation but some have quality educational and research institutions universities that are less costly to undertake such endeavours (Brundenius et al., 1993; Pack, 2000). Some developing and LDCs can offer conducive and environmental conditions that can test performance of some technologies under different environments. However, the tests and pilot projects for technologies should benefit the LDCs but not to exploit their human capital and environment. Conversely, the LDCs have to facilitate and create an enabling environment through strengthening of educational institutions especially in technical and scientific capacity (Mertz et al., 2000; Ruttan, 2001). In addition, some important transfers of technology in production engineering are non-proprietary and are likely to benefit the LDCs. The common transfer of 'soft' technology is through foreign knowledge provision by consulting groups and individuals with technical expertise and advisory skills.

The industrialised and developed countries have different technological needs as compared to the developing and those with economy in transitions (EITs). Similarly, the needs of the least developed countries (LDCs) differ from those of the other categories of countries. Therefore, the means of implementing technology transfer will differ from the one that might take place between the developed and the developing countries and EITs. Figure 2.2 illustrates the level of Gross National Income (GNI) per capita for World Bank member countries in 2001. Lesotho is in the category of the least developed countries. It belongs to countries with GNI below US$745 per capita. On the other hand, the country such as South Africa is among the developing countries category with GNI per capita of US$ 2820 (World Bank, May 2003).

Figure 2.2: The Level of GNI for World Bank Member Countries



Source: World Bank, May 2003

There is a huge economic gap between the least developed countries and the developed countries as shown on Figure 2.2. Considering the technological and economic level of countries such as Japan, it is evident that priority on technology transfer in the LDCs such as Lesotho must be in training, institutional support as well as in information support. However, the country can also benefit from the technology partnerships like joint ventures as well as collaborative research and development from the developed countries and the developing countries like South Africa. The partnerships lead to investments as well as economic and technological growth. In addition, some of the international trading regulations governing technology transfer such as licensing proprietary rights can be disadvantageous towards technology transfer process because they are rather costly and time consuming when using all the terms and rules of the technology transfer process. Thus, the least developed countries are seeking more technological services and sustainable development. Hence their requirements must be the first priority rather than the terms and rules of technology transfer (Pack, 2000).

2.6 Concluding Remarks

The literature review generally indicates that transfer of energy technology is one of the strategies that enhance and ensure sustainable development in countries. Most authors as well as international agreements and obligations agreed that technology transfer requires commitment of both the technology supplier and the recipient. The literature also emphasises that some mechanisms of technology transfer are difficult to apply in the least developed countries. Therefore, selection of transfer mechanism plays an important part in the process of technology transfer. The transfer mechanisms also differ according to the priorities of the main participants in the transfer process and motivation to the recipient especially the LDCs. Training is one of the essential factors that can determine the success of transfer process.

The mentioned areas of technology transfer need improvement and development because the priority of many LDCs such as Lesotho is to enhance indigenous human resource capacity. Very little or no private organisations in Lesotho in late 1990s except the utilities and government departments that can handle high capital and technology intensive projects when assessing the economic status of the country in Figure 2.2. The indicators such as the status of science and technology infrastructure, academic and research institutions, level of industry and financial institution shows that the country still requires technical support as physical machinery, infrastructure and technical expertise. The reviewed technology transfer mechanisms and processes differ in degree of their application. Some mechanisms such as collaborative research and development requires similar level of technological understanding by the partners while some mechanism such as information and institutional support can be beneficial to LDCs without technical expertise. The literature also indicates that the approach and the mechanisms of technology utilised differ according to the priorities of the involved countries and entities.

All the discussed mechanisms and the related factors need a comprehensive structure that will show the role of the supplier and the recipient respectively. The structure must be applicable to analyse all the different stages and components of technology transfer. The structure or framework must provide the guidelines to determine the areas where technology transfer is successful and where the gaps exist. The next chapter discusses the different transfer models and the development of integrated framework for technology transfer that will be responsive to all responsive to all countries without their economic status.

CHAPTER 3

DEVELOPMENT OF AN INTEGRATED FRAMEWORK FOR TECHNOLOGY TRANSFER

3.1 Introduction

The current changes within the energy sector globally focus on the liberalisation of the sector and wider access to modern energy especially to the poor. Their trends involve utilisation of energy technologies and decentralisation of electricity generation to minimise imports, transmission and distribution costs from generation to the end users. The reduction of energy supply costs implies improving the utilisation of indigenous energy resources where possible especially when the investment is technically and economically feasible. Another strategy, which is the interest of this work, is to transfer appropriate, maintainable and replicable energy supply technologies from developed countries to developing and least developed countries. However, it is rather difficult to find a situation where both the recipient and the supplier of technology sharing common interests in the process of technology transfer as mentioned in the previous chapter. The technology suppliers may have priority on expanding markets for transferred technology while the interests of the technology recipient were on enhancement of indigenous capacity building and sustainable development.

The success of transferring energy technologies requires conducive, appropriate and robust guidelines for such initiative without prejudicing the priorities of both the supplier and recipient. The aim of this chapter is to develop a framework for the transfer and acquisition of energy technology from the producers and manufacturers to the technology recipient. The chapter will explore different technology transfer models, flow charts and frameworks with the intention to formulate an integrated framework for technology transfer. The formulation of an integrated framework will follow an intensive analysis, review and comparison of different explored technology transfer frameworks. The intended integrated framework has to be comprehensive and relevant to the energy technologies. The framework will include guidelines for monitoring and evaluation of the transfer process as well as a tool for the transfer of selected energy technology. In addition, the framework should be meaningful to facilitate the access to the technology intended by the recipient in an effective and efficient manner.

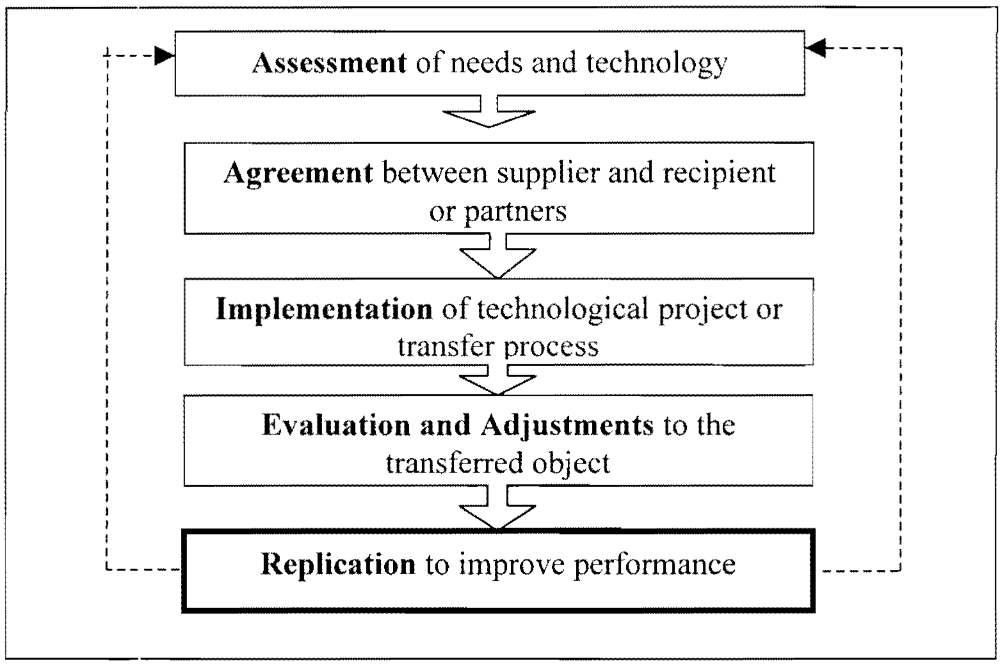
3.2. The Technology Transfer Frameworks

Different institutions and authors have suggested various frameworks and models that can assist the process of technology transfer. This section explores five theoretical frameworks of the technology transfer developed for assessing and analysing the effectiveness of the transfer process.

3.2.1 The Five Stage Technology Transfer Process

The Intergovernmental Panel on Climate Change (IPCC) suggests a model of technology transfer as a five-stage flow chart with a feed back loop. The first stage is technology assessment, followed by agreements between the recipient and supplier or partners. The third stage is implementation of the agreement and the fourth stage is evaluation and adjustments of the implemented technology. Subsequently, the adjustment and evaluation decision will lead to replication of technology. The replication capability will assist the recipient to evaluate and adjust the technology in order to suit it to the local conditions and to improve its performance. Another cycle will start after technology replication (Mertz et al., 2000). Figure 3.1 below illustrates a schematic framework proposed by IPCC.

Figure 3.1: The five stages of technology transfer

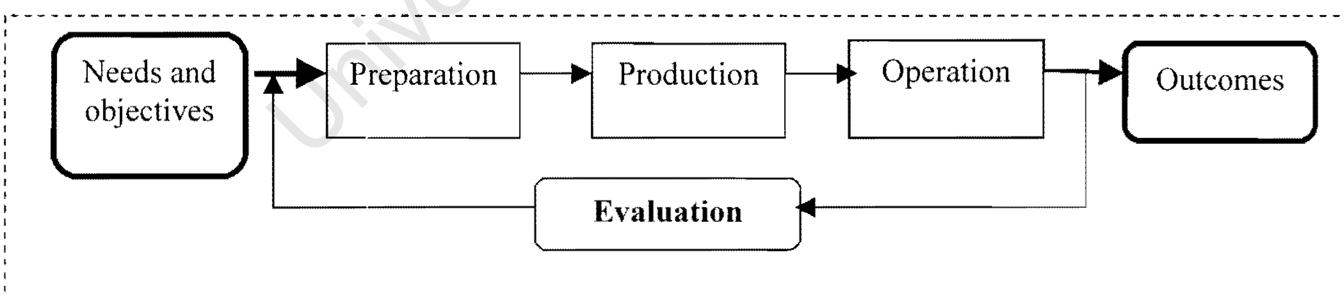


Source: Mertz et al., 2000

3.2.2 Model for Technology Transfer

The second model for technology transfer proposed by Moore, G., Putranto, K. and Stewart D. (2003) consists of five stages with feed back loop of evaluation. The main stage is identification of technological needs and objectives of technology recipient. The next stage is preparation by the recipient to receive technology. Thereafter, technology production stage takes place, followed by the routine operations stage. The evaluation as a feed back loop will determine the failure or gaps and propose the adjustments using the same procedure as described as in section 3.2.1. If the process is successful, the recipient will utilise the outcomes of the technology transferred. Figure 3.2 illustrates the model with technology transfer as a process, while Table 3.1 indicates the characteristics of the technology transfer stages.

Figure 3.2: Model for Technology Transfer



Source: Moore et al., 2003.

Table 3.1: Activities of the Technology Transfer Stages

Needs and Objectives	Preparation	Production	Evaluation
	Identification of technology	Design of technology	Dynamic learning
	Feasibility study	Equipment of technology	
	Specification of technology	Manufacturing or installations	
	Negotiations	Adaptation of technology	

Source: Moore et al., 2003.

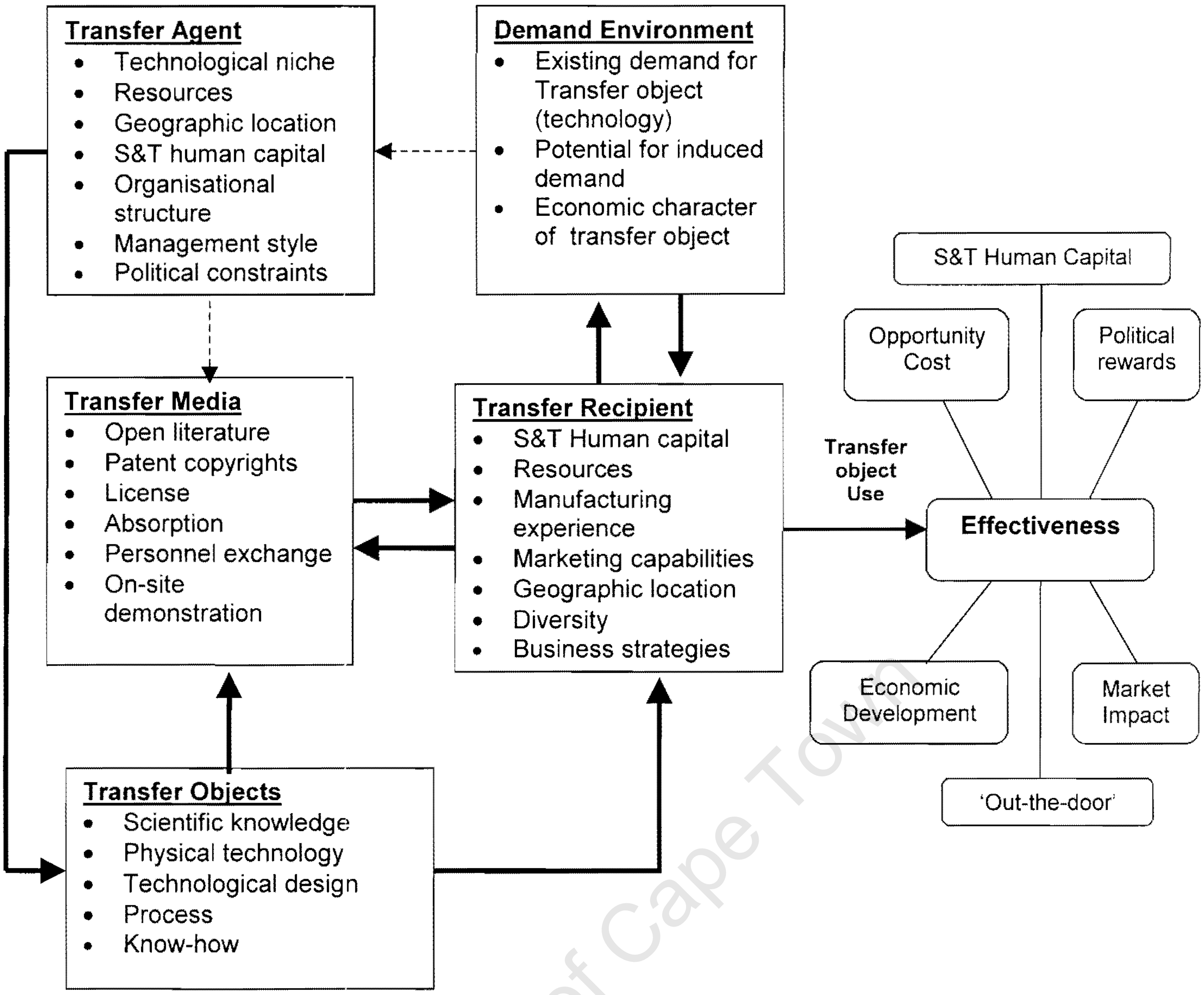
The signing of an agreement is part of the project preparation or technology initiation. Signing of contracts, treaties, and memorandum of understanding at government-to-government level lead to detailed feasibility studies and more familiarisation of the identified technology. Therefore, preparation is important because sometimes the benefits appear to be prominent as compared to the risks at the preliminary stage while the situation may be the other way round in the process.

3.2.3 The Contingent Effectiveness Model of Technology Transfer

The third model is the Contingent effectiveness model (CEM) for organising technology transfer as developed by Barry Bozeman (2000). The model consists of the six essential stages, which interact and supplement each other along the life cycle of technology transfer. The model also indicates the six main dimensions that will determine the effectiveness of the transfer process. The contingent effectiveness model also has flexibility as the stakeholders to the technology transfer process, which normally have different objectives and criteria to determine effectiveness of the transferred or acquired technology.

The demand for technology initiates the flow chart. The demands are relative to conditions such as the actual technological needs and the status of the economy especially at national level. The recipient country or organisation uses all its resources such as government and management strategies to determine the areas that need technological support. Technology transfer agents such as government institutions or private organisations may determine the mode or object of technology with or without considering transfer. Implementation delays, contingencies, government regulations, economic factors and politics can affect agreements at the advanced stage of the transfer (Bozeman, 2000). However, compliance with the contract agreement protects one stakeholder against the other especially where the recipient is vulnerable as compared to the supplier. Technology transfer media include open literature, intellectual patent rights, license or technological personnel exchanges or research demonstrations. One of the common means of technology transfer is cooperation of research and development agreements. The transfer objects can be physical equipment or machinery, technical knowledge or designs (Bozeman, 2000). Figure 3.3 shows the different stages of model and the factors that determine the effectiveness of the technology transfer. Although developed for domestic technology transfer, it is also applicable at the international level.

Figure 3.3: Contingent Effectiveness Model (CEM).



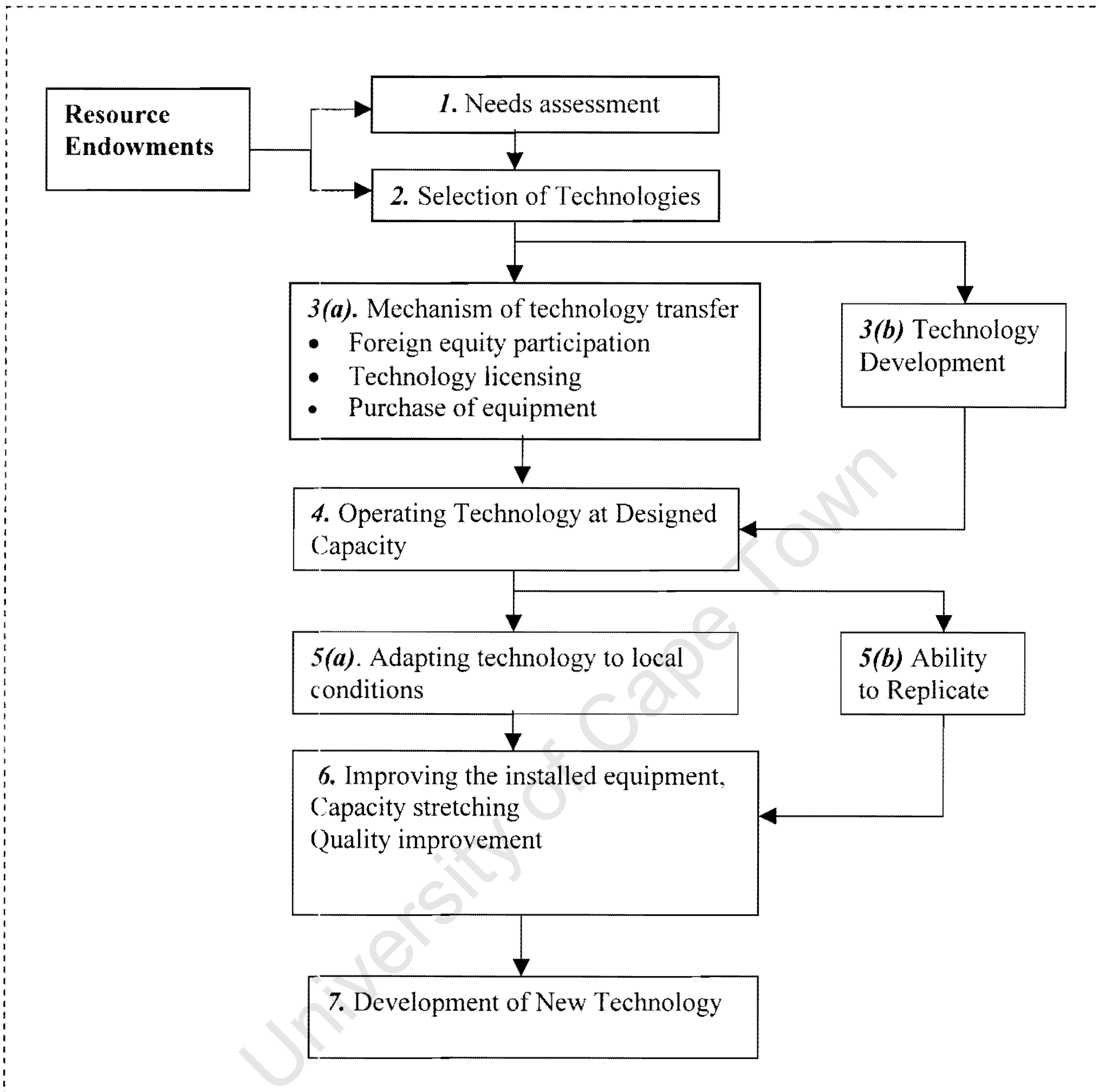
Source: Bozeman, 2000

Figure 3.3 also shows that the availability of science and technology human capital, manufacturing or operational experience, marketing and as well as business strategies constitute an enabling environment required by the recipient to be able to absorb technology effectively. The absence of such capability creates further technological needs (Bozeman, 2000). In addition, the transferred technology may be more effective if it has positive impact on markets and economic development as well as enhancing the scientific and technical human capital. The other important parameter for successful technology transfer is political stability and clear indication of opportunity costs for transferred technology as compared to other alternatives.

3.2.4 The Various Steps for Technology Transfer Model

The fourth relevant model indicates the seven steps with two overlapping stages that are essential in technology transfer process according to Kathuria (2002). The model shows that the foremost factor that determines technology transfer is resource endowments. Resource endowment of a country will assist in undertaking the assessment of needs as well as technology identification and selection. Many developing and least developed countries are eager to improve their indigenous capacity building and technological self-sufficiency in all sectors including the energy sector. If the resources endowments are not sufficient, it is important for the recipient country to use all the technology transfer opportunities in order to acquire tangible and intangible resources to develop technological capability and capacity (Cray et al., 2002). The stages follow each other until technical capability is sustainable to develop other products as Figure 3.4 illustrates.

Figure 3.4: Flow Chart of the Various Steps of Technology Transfer



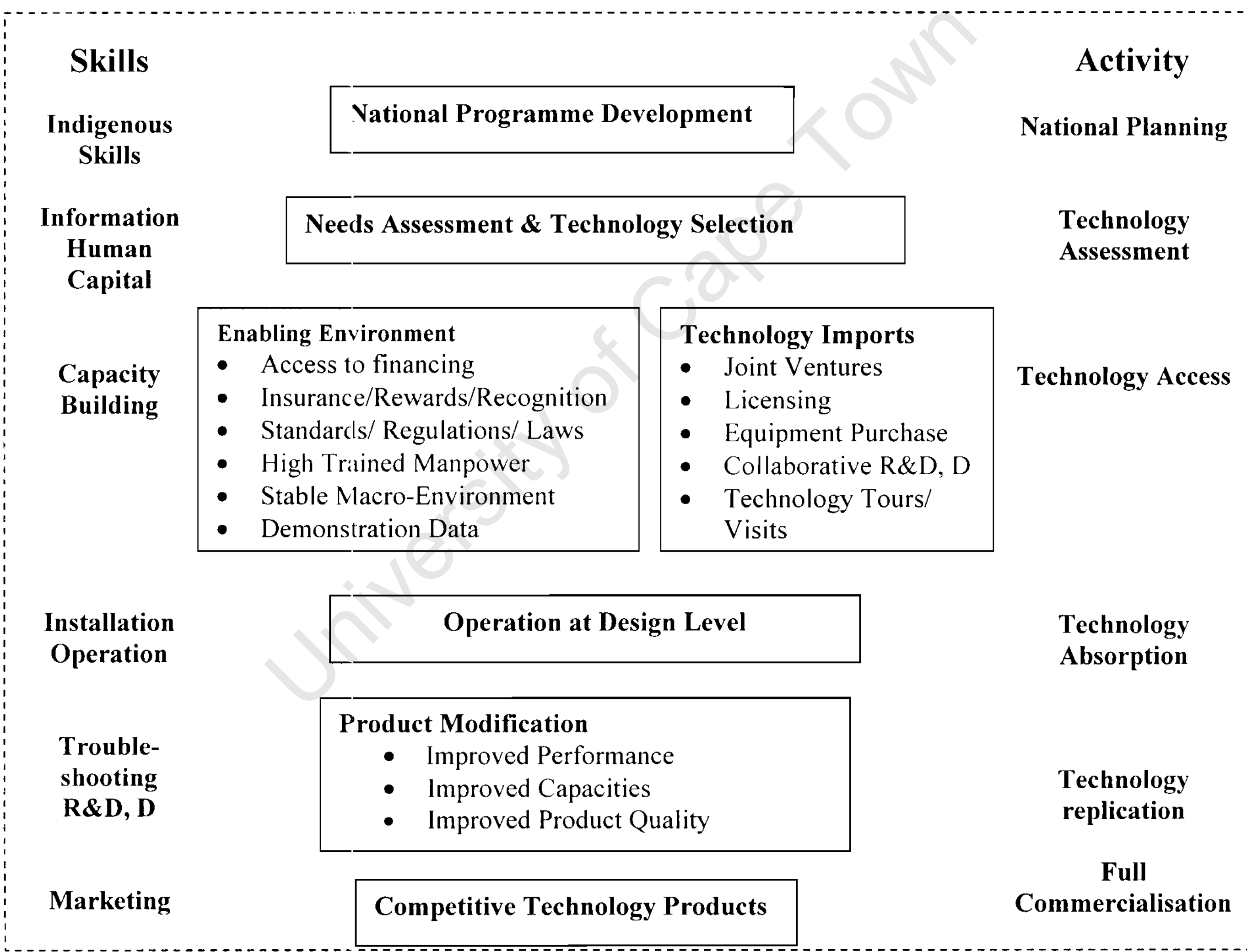
Source: Kathuria, 2002

The second stage in the model is technology selection. After this stage, there will be technology development into operational stage. However, before reaching operational stage there must be mechanism of importing or acquiring it from the supplier. This process can occur through either foreign direct equity contract or technology licensing mechanisms. On the other hand, technology transfer can happen through direct purchasing of machinery, equipment, blueprints or designs. Thereafter, technology must operate at the designed capacity especially when it is in a form of physical equipment and machinery. Then the recipient must find the means of assimilating and adapting technology to the local conditions and environment. However, the indicated stages also indicate that the technology must be replicable in order for the end users to adapt it to local environment. The stages in Figure 3.4 also illustrate that the capability to replicate technology also assists to improve technology from its designed capacity to advanced levels. Eventually, the recipient will be able to develop new technologies to address the technological needs in the recipient country or organisation and transfer them to others when necessary.

3.2.5 The Conceptual Framework for Technology Transfer Cooperation

This conceptual framework for technology transfer cooperation can be very useful because it will assist both least developed countries and developing countries to enter bilateral agreement with developed countries. The aim of the framework is to ensure that the recipient capability to assimilate technology. A major feature of the framework is the creation by the recipient country to create an enabling environment for attracting and protecting foreign direct investments. The framework starts with preliminary activity analysing the national programme to identify the indigenous resources skills that are essential for the needed technology. The framework comprises of the different stages illustrated in Figure 3.5 below.

Figure 3.5: Conceptual Framework for Technology Cooperation



Source: Davidson, 2000

The first stage of conceptual framework for technology transfer is needs assessment and technology selection, which comprise local skills and its enhancement to ensure that the skill of technology selection be sustainable. The second stage is technology initiation and it comprises of importation of technology and its assimilation. This stage can only be effective if the technology recipient has created an enabling environment, as it is the most important factor for importing useful technology. The last stage consists of technology replication and commercialisation activities.

3.3 Analysis of Different Frameworks: basis for Suggestion of an Integrated Framework for Technology Transfer

The frameworks and models of technology transfer reviewed above differ in approach but they all emphasise that the both the recipient and the supplier of technology must benefit from the transfer process. However, the analysis of those different frameworks above provides the background to the development of an integrated framework that will guide the effective analysis of technology transfer and cooperation. In general, technology transfer involves two main parties, the supplier of technology and the recipient of technology. In addition, the primary objective of transfer is to benefit both parties, thus resulting in a win-win situation.

In the first case reviewed as shown in Figure 3.1, the assessment process was the starting point and it includes identification of needs. The next case shown in Figure 3.2 illustrated that needs and objectives are the main issues driving the technology transfer process. The case shown in Figure 3.3 stressed the demand for technology and economic factors as the main factors to initiate the transfer process. This view was expressed in the case shown in Figure 3.4 that identified needs assessment as the first activity, which should rely on the resource endowments in assessing the needs and technology (Kathuria, 2002). Similarly, the case shown in Figure 3.5 illustrates the need for correlating attributes of national development with technology needs as a preliminary exercise while considering the financial and indigenous resources.

Therefore, using the above cases as a guide, the preliminary stage in assessing technology transfer especially in the LDCs and developing countries should start with national development programme as advocated in the national development plan. However, this stage requires knowledge of national resources and endowments as the availability of such resources will assist in estimating the demand, assessing the needs and also prioritise these needs according to the national development programme.

The second stage is selection of technology from the different technological options and suppliers while considering the developmental status of the country, especially for LDCs that lack several supporting technical aspects. It worth noting that technology includes physical machinery equipment, technical expertise, design blueprints and technical specifications. The third stage is technology negotiations and technology access. Technology negotiations include contract agreements based on the choice of mechanism for technology access. The mechanisms of transfer include joint ventures, licensing, foreign direct investments as well as choice of machinery and equipment. The fourth stage, which is a very important, is the assimilation and utilisation of technology in accordance with the designed specifications. The fifth stage is adaptation of technology to the local or specific environmental conditions. Thereafter, capacity is necessary to improve technology beyond the designed specifications and to continue undertaking troubleshooting to overcome any problems encountered during its operations. Table 3.2 illustrates the comparative review of the model and frameworks discussed.

Table 3.2: Comparison and Categorisation of the Stages of Technology Transfer

	Frameworks and Models for Technology Transfer				
	Figure 3.1: Five Stage with feed back loop. Source: Mertz et al., for IPCC, 2000	**Figure 3.2: Model for technology transfer.** Source: Moore et al, 2003	**Figure 3.3**: Contingent Effectiveness Model (CEM). Source:** Bozeman, 2000	**Figure 3.4: The Various Steps of Technology Transfer. Source:** Kathuria, 2002	**Figure 3.5: Conceptual Framework for Technology Cooperation.** Source: Davidson, 2002
Level 0				Resource Endowments	National Programme
Level 1	Assessment of needs and technology	Needs and Objectives	Demand Environment • Existing demand for Transfer object (technology) • Potential for induced demand • Economic character of Transfer object	Needs assessment	Needs Assessment
Level 2		Preparation through Technology Identification	Identify Transfer Objects • Scientific knowledge • Physical technology • Technological design • Process • Technical know-how	Selection of Technologies Choice varies from Scientific knowledge • Physical technology • Technological designs, • Blueprints, Process • Technical know-how	Technology Selection Choice varies from Scientific knowledge • Physical technology • Technological design • Blueprints, Process • Technical know-how

Level 3	Agreement between supplier and recipient or partners	• Feasibility study • Specification of technology • Negotiations	Transfer Agent seeking technology (Government, agency, university, private, setting characteristics, personnel, culture) • Technological niche • Resources • Geographic location • S&T Human Capital • Organisational structure • Management style • Political constraints		Enabling Environment • Access to financing • Insurance/ Rewards /Recognition • Standards/ Regulations/ Laws • High Trained Manpower • Stable Macro-Environment • Demonstration Data
Level 4			Transfer Media • Open literature • Patent Copyright • License, CRADA • Absorption • Informal meetings • Personnel exchange • On-site demonstration	Mechanism of technology transfer • Foreign equity participation • Purchase of physical equipment • Technology licensing	Technology Imports mechanism • Equipment Purchase • Joint Ventures • Licensing • Collaborative RD& D • Technology Tours/ Visits

Level 5	Implementation of technological project or transfer process	Production • Design of technology • Equipment of technology • Manufacturing or installations	Transfer Recipient (firm, agency, consumer, academic institution) • S&T Human capital • Resources • Manufacturing experience	Operating Technology at Designed Capacity	Operation at Design Level
Level 6	Evaluation and Adjustments to the transferred object	Adaptation of technology	Transfer Recipient (firm, agency, consumer, academic institution) • S&T Human capital • Resources • Geographic location	Adapting technology to local conditions	
Level 7	Replication to improve performance			Improving installed equipment, Capacity stretching Quality improvement	Product Modification • Improved Performance • Improved Capacities • Improved Product Quality

Level 8		Evaluation Dynamic learning	Transfer Recipient (firm, agency, consumer, academic institution) • S&T Human capital • Resources • Manufacturing experience • Marketing capabilities • Diversity • Business strategies	Development of New Technology	Competitive Technology Products
Level 9			Effectiveness of transferred technology • Market Impact • Opportunity cost • S&T human capital • Economic development • Political		

Sources: Bozeman, 2000; Mertz et al., 2000; Davidson, 2002; Kathuria, 2002, Moore et al., 2003.

**The Contingent effective Model has processes that interact as illustrated in Figure 3.3.

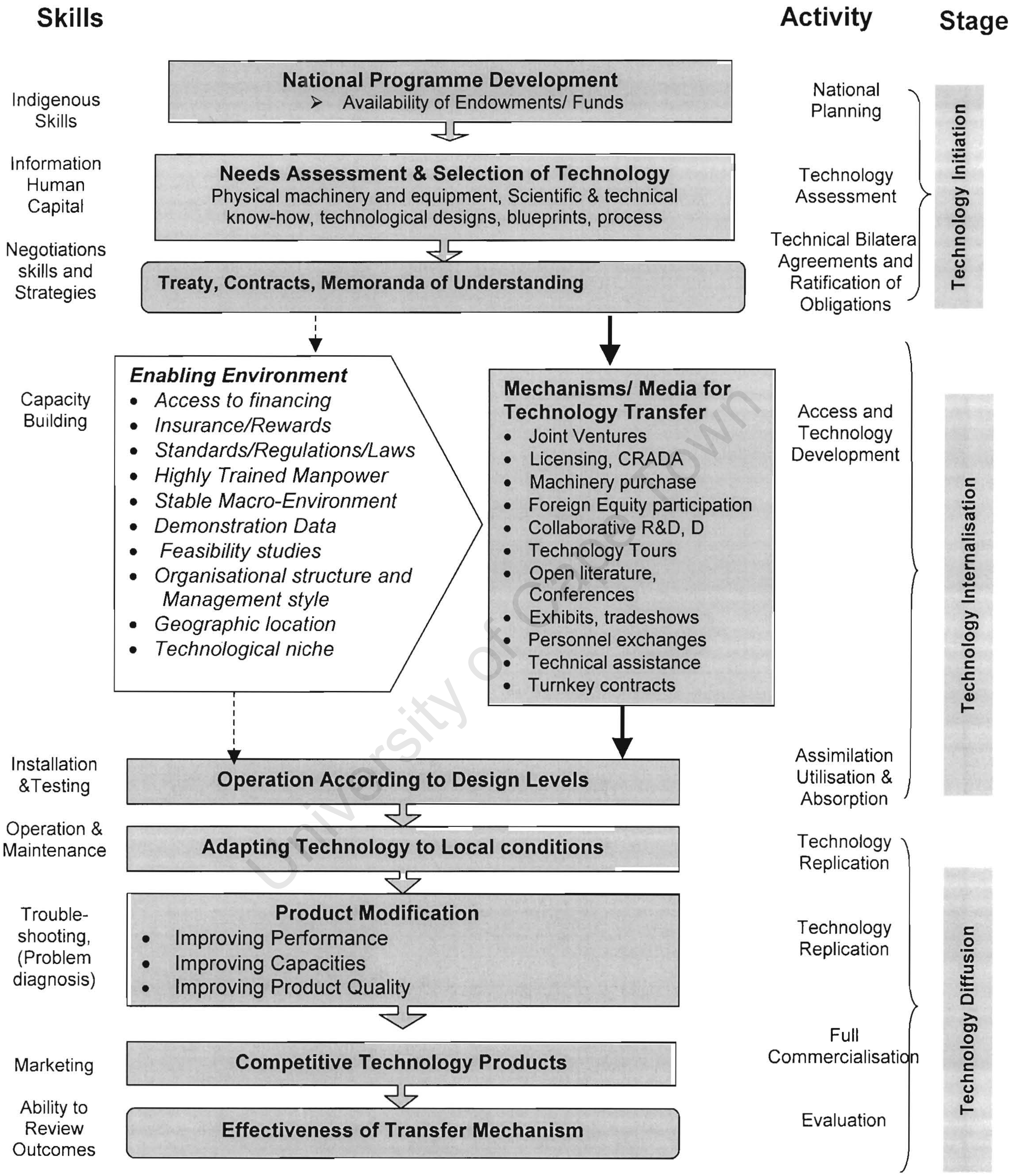
These different frameworks have strengths and weaknesses. The first discussed model shown in Figure 3.1 is brief although the five stages are all necessary in the process of technology transfer but the model does not indicate the necessary skills or conditions required for each stage to happen. The framework is more relevant for transfer processes within the developed countries where the basic technical skills are available. The second discussed technology transfer model shown in Figure 3.2 is also brief and indicates the necessary activities during the stages of preparation and production. However, the model also does not indicate the responsibility or activities of the recipient and the technology supplier in each stage of technology transfer. The model also does not specify the technology transfer mechanisms and the sectors where the model is likely to be applicable. The model seems to be more applicable at international level especially where technological capability is at advanced stage. The third model is 'contingency effectiveness model' shown in Figure 3.3. It has important stages of determining the effectiveness of the transfer process. The model shows the objects and items referred as technologies. The model is applicable but requires understanding of each stage and its relation to others, as it is interactive. Therefore, its application is also limited for the Africa including the least developed countries such as Lesotho although some of the stages are important.

The fourth discussed framework is a 'stages model' as shown in Figure 3.4. The model is also specific and logical. The intention for development of the model was to address the technological needs in a developing country. Therefore, the stages are all important for Africa including Lesotho, as it shows resource endowments as the preliminary stage for transfer process. The model shows few mechanisms for technology transfer but does not show how technologies to enhance sustainable development. The fifth model discussed is 'conceptual framework for technology cooperation' shown in Figure 3.5. The model is relevant, specific and appropriate as it illustrates the responsibilities of the technology supplier and the recipient simultaneously. The framework shows logical stages together with necessary skills and activities required for accomplishing each stage effectively. The development of framework considered the developed countries as technology suppliers, and developing and least developed countries as recipient. Therefore, it is eligible for applicable at international level, in Africa as well as in the least developed countries such as Lesotho. Although the framework is responsive at international level however, it does not indicate the technology transfer negotiation stage. It does not show the evaluation or review activity. However, the conceptual framework seems to be the most relevant to the least developed countries especially for important technological areas such as energy sector. Therefore, the conceptual framework will form a basis for development of integrated framework for technology transfer while the other models will strengthen it to make it more applicable and responsive at international level, Africa and Lesotho as a LDC.

3.4 The Suggested Integrated Framework for Technology Transfer

The analysis of the different models shows that there are some similarities in different stages of technology transfer though there are also differences. Therefore it is important to combine the important elements of each framework in order to develop and integrated framework that will be responsive at international level, for Africa and Lesotho as a LDC. The suggested model that is comprehensive and relevant to the energy technologies as illustrated in Figure 3.6.

Figure 3.6: Integrated Framework for Technology Transfer



The integrated framework illustrated on Figure 3.6 indicates the important steps and procedure for effective transfer of energy technology through technology initiation to technology operations and diffusion stage where the outputs are accessible to the market. It is also important to have cooperation between the recipient country and the suppliers in order for the framework to be effective.

3.5 The Stages of Integrated Framework for Technology Transfer

The three main stages of the technology transfer process are technology initiation, technology internalisation and technology generation. Technology initiation emphasises that the recipient take a leading role in defining and expressing interest in a certain technology depending on the needs, priorities and the objectives. In order to assist the LDCs to attain development and technological expertise, needs assessment must start at the planning level of the responsible government departments or agencies for policy making on energy issues and technology. The stage involves identification and selection of the technology. The process requires broad knowledge of the different technologies for effective comparison and benchmarking based on the recognised international standards. The level of technology negotiations, bilateral agreements, and treaties as well as memorandum of understanding regarding the selected technology also adds to the technology initiation stage.

The second stage is technology internalisation. It includes creation of an enabling environment and technology adaptation. This stage also includes political stability, import legislation, standards and specifications, infrastructure development and acquisition of the selected technology. The aim, at this stage, is to eliminate the situation of selecting technology that is not conforming to the specifications. In addition, technology requires modifications in order to adjust to local conditions. However, the modifications must avoid altering the design specifications and standards. Research, development and demonstration (RD&D) are important at technology internalisation stage. Therefore, availability of local expertise and skills are necessary to ensure absorption of technological skills. The last stage of integrated framework for technology transfer involves the activities such as technology replication, full commercialisation and evaluation of the entire transfer process. The commercialisation step requires marketing skills in addition to the stipulated technical expertise as stated in the fifth model reviewed. Evaluation activity is important to determine success of the transfer process and of the technology transferred. Evaluation considers problems and risks that could have incurred during assessment, agreement, development, and implementation as well as during the initial operation of the technology. The evaluation activity will also consider the impacts, the relevance, efficiency and sustainability in addition to effectiveness of the transfer process.

Evaluation for impact of technology focuses on overall goals and objectives of the recipient country towards the acquired and installed technology. Evaluation for efficiency focuses on the results, the involved activities as well as the means utilised. Efficiency analysis also determines how the used mechanisms were able to transform the resources and inputs into concrete project results. The relevant evaluation focuses on the goals, objectives and results with intention to assess the scope of technology transfer project in relation to the problems and priorities of the partners and beneficiaries involved. The effectiveness primarily measures the appropriateness of the goals chosen to the ideal situation and degree of their achievement. The analysis of technology transfer effectiveness determines how the outcomes and production contribute to the achievement of the technology transfer purpose using the indicators. The indicators in this case include an analysis to determine the actual transferred technology, market impacts, economic development, status of scientific and technical human capital, opportunity costs, and political acceptability level. Lastly, the evaluation process determines the sustainability of the technology transfer project with focus on goals, objectives, results, activities, and means. The sustainability tool determines whether the transferred technology is appropriate, replicable and maintainable. It also determines whether the developed recipient capacity is able to replicate and maintain the technological systems without external assistance.

3.6 Concluding Remarks

The literature of technology transfer models indicates several important mechanisms and elements that are necessary when implementing power-producing technologies. The initial elements suggested in the literature and transfer models on Figures 3.1, 3.2, 3.3, 3.4 and 3.5 show the needs assessment as a primary issue to initiate technology transfer. The basis for development of integrated framework in Figure 3.6 was elaboration of the discussed technology transfer models and flow charts. The focus was mainly on the appropriate and applicable elements in the energy technologies. The integrated framework for technology transfer is can be useful at international level, African states and LDCs such as Lesotho, because four of the five discussed frameworks also considered the case studies within the developing countries.

Technology becomes replicable when the recipient is able to improve performance, capacity and quality with little or no assistance from the technology suppliers and manufacturers. Similarly, understanding and maintaining of the energy technology becomes attainable if trainable local personnel to be operators, technicians, engineers, and engineering managers are available (Cray et al., 2002). Moreover, well-maintained and replicated energy technologies are easier to reach commercial status. Energy technology will then enhance the economic level, improve their accessibility, meet growing electrical energy demand, reduce environmental impacts and assure sustainable development.

It is essential for the country or any organisation to assess the opportunities for technology transfer and to create an enabling environment for such process to happen effectively. The framework can work as important guidelines, which the country can apply to test whether foreign-based investment contributes towards technology transfer irrespective of being in the energy sector. The development or adoption of technology transfer framework will also work as a planning tool for the future international and bi-national projects that involve foreign-based companies and personnel. The guidelines will assist the technology recipient to determine whether technology is operating at its design level, and whether is adaptable to local environment as well as being replicable.

CHAPTER 4

THE POWER GENERATION SECTOR IN LESOTHO

4.1 Introduction

The Kingdom of Lesotho is an inland country in the Southern Africa region surrounded by the Republic of South Africa. The country covers an area of 30 355 square kilometres with 60 percent range lands, 31 percent mountainous region and only 9 percent of arable land. The population is approximately 2.17 million with the growth rate of 1.5 percent per year (Bureau of Statistics Lesotho, 2003). The population density of Lesotho in 2001 was approximately 70, (persons per square kilometre). This chapter will discuss a general overview of the historical developments in the power generation sector in Lesotho and comment of its position to acquire energy technologies.

4.2 Historical Background of Power Generation in Lesotho

The Lesotho power sector consists of four mini hydropower systems and one large hydropower system. The estimated exploitable hydropower potential in Lesotho is between 450 and 600 MW (Department of Energy-Lesotho and GTZ, 1988). Lesotho Electricity Corporation (LEC) operates four mini hydropower plants and the diesel-powered backup systems. One hydropower Mantsonyane (2MW) supplies the existing LEC distribution network. The other two mini hydropower plants, Semonkong (180kW) and Tlokoeng (670kW) supply isolated networks, while the Tsoelike (400 kW) mini hydropower system supplies the town of Qachas'Nek with backup from Eskom distribution network. Muela hydropower station is only the large power supplying entity with capacity of 72 MW. The Table 4.1 indicates the characteristics of the four mini hydropower plants in Lesotho.

Unfortunately, the mini hydropower plants are not performing to their design levels because of problems that they have been experiencing since they were commissioned. Semonkong and Mantsonyane have experienced severe drought problems, while the Tlokoeng and Tsoelike mini hydropower plants have sedimentation problems. These barriers led to the deterioration in operations of energy technologies. Subsequently, the isolated schemes only operate for about 14 hours a day and mainly use diesel generators instead of using them as back-up systems according to designs and plans as they were planned for.

The most important factor for the poor performance of these plants emanated from the fact that the hydropower plants were initially under the operations and maintenance of the foreign personnel. The plant started to deteriorate, as there were hardly qualified local personnel to replace the foreign personnel after they leave. In addition, the local personnel were hardly involved in the designed and management of these projects as the government never insisted in having competent local personnel as counterparts to the foreign experts. Moreover, the government and responsible utility did not monitor the projects properly to ensure that training as technical knowledge transfer continues according to the agreed schedules and priorities. It is important to discus all the mentioned mini hydropower technologies to analyse their performance and level success in terms of technology transfer. Table 4.1 indicates the characteristics of the four mini hydropower plants in Lesotho.

Table 4.1: Characteristics of mini hydropower systems in Lesotho

Character	**Mantsonyane**	**Tsoelike**	**Tlokoeng**	**Semonkong**
Funding Source	Norway	France	France	Norway
Construction Cost (R million)	20	15	13	7
Completed Date	16/02/89	05/02/90	05/02/90	04/11/88
Hydro (kW)	2000	400	670	180
Design Energy (GWh/a)	6.7	2.6	3.3	0.6
Annual design Load factor (%)	38.2	74.2	56.2	34
Back-up Diesel (kVA)	0	200	200	120
Reservoir				
Storage volume (m^3)	940 000	Run-off-river	157 000	Run-off-river
Dam/weir type	Rock fill	Concrete gravity	Concrete gravity	Concrete gravity
Dam/weir height (m)	18	4.1	7.1	2.5
Crest length (m)	120	48	76	95
Headrace Tunnel				
Length (m)	700	522	134	300
Cross sectional area (m^2)	12.3	2.6	4	1.15
Equivalent diameter (m)	3.96	1.82	2.26	1.21
Tunnel lining	Unlined	Sprayed concrete	Unlined	Buried concrete pipe
Penstock				
Material	Steel	Steel	Steel	Glass/fibre/ Polyester
Length (m)	20	50	77.5	150
Diameter (mm)	1400 and 1700	800	800	1200/1000
Transmission Line				
Voltage (kV)	33	33 & 11	33	11
Length (km)	66	30 & 7	35	3.2
Turbines (large set No 1)	Francis	Francis	Francis	Francis
Power (kW)	1563	263	486	198
Net Head (m)	35.5	27.88	50.42	18
Flow (m^3/s)	5.13	1.1	1.1	1.18
Rated Speed (rpm)	500	1000	1000	750
Turbine efficiency	87.6	87.5	89.4	87.7
(Small set No 2)				
Power (kW)	521		223	121
Net Head (m)	35.5		50.84	28.2
Flow (m^3/s)	1.71		0.5	0.5
Rated Speed (rpm)	750		1500	1000
Turbine efficiency (%)	87.6		89.5	87.6
Total turbine power output (kW)	2084	384	709	198
Total generated kW at 96% power factor	2001	369	681	190
Total flow (m^3/s)	6.84	1.6	1.6	1.28
Flow per energy (m^3/kWh)	12.31	15.63	8.46	24.24

Source: Department of Energy-Lesotho and LEC

4.2.1 Mantsonyane Mini Hydropower Station

Mantsonyane is the largest mini hydro plant with an installed capacity of 2MW and has been operating since 1989. The Norwegian government provided financial and technical resources for this plant. The station is located in the central part of Lesotho where it supplies the town of Thaba-Tseka and Mantsonyane service centre village. The station do not have a diesel back-up system because it is connected to the national grid through a 33 kV line and it assist in levelling peak demand so reducing power imports from Eskom, South Africa. Table 4.2 shows the performance level of the station from 1996 to year 2000.

Table 4.2: Mantsonyane mini-hydropower station

Years	1996	1997	1998	1999	2000	Average
Generation (MWh)	2886	3103	3866	1587	4003	**3089**
Percentage of Hydro (%)	100	100	100	100	100	**100**
Peak Demand (kW)	2250	2300	2300	1750	2250	**2170**
Annual duration of Generation (hrs)	8551	8994	8847	9069	8896	**8871**
Using the load factor = (Energy/ (peak demand *Time)) (%) *(Designed 38.2%)*	15	15	19	10	20	**16**
Hydropower technology Utilisation (% Actual/designed energy utilised) (%)	43	46	58	24	60	**46**
Designed energy supply per annum (MWh)						**6692.6**

Source: LEC and Department of Energy-Lesotho

However, the hydropower capacity utilisation is only 46 percent, which implies it is under-utilised.

4.2.2 Tsoelike Mini Hydropower Station

Tsoelike consists of two Francis turbine-generating units of 275 kW and 1254 kW capacity and a back up system made of two diesel generators of 200 kVA and 320 kVA. The station was originally isolated but since 1997, it has a cross-border connection arrangement between LEC and Eskom of South Africa in the Eastern Cape Province. There are ongoing negotiations between LEC and Eskom to increase supply from 500 kVA to 1,000 kVA. Table 4.3 summarises the performance of Tsoelike hydropower up to year 2000.

Table 4.3: Tsoelike mini-hydropower station

Years	1996	1997	1998	1999	2000	Average
Hydro turbine output (MWh)	12	100	58	40	23	**47**
Diesel generator output (MWh)	243	76	1	0	0	**64**
Percentage Hydro (%)	5	15	13	2	1	**7**
Peak demand (kW)	420	443	550	652	638	**541**
Annual duration Generation (hrs)	8673	2337	1192	168	71	**2488**
Using the load factor = (Energy/ (peak demand *Time)) (%) *(Designed 74.2%)*	7	17	9	36	51	**24**
Hydropower Technology Utilisation (Actual/designed energy utilised) (%)	10	7	2	2	1	**4**
Designed energy supply per annum (MWh)						**2600**

Source: LEC and Department of Energy-Lesotho

Table 4.3 also shows that the hydro electricity only contributes 7 percent of the total electricity consumed in Qacha'sNek for the period stated. In general, the plant utilisation is extremely low because of the cross-border connection to the town of Qacha'sNek and the best year was in 1997 when it contributed 15 percent share. The connection to Eskom network has increased the reliability of electricity supply, but there has been no hydropower generation since 2000 due to failed circuit breakers and lack of capable local staff and facilities to undertake the repairs. Usually, the operators always send the high voltage (HV) circuit breakers to South Africa for repairs. This indicates that the level of technical expertise is low because of no suitable local personnel to undertake the job. Then such breakdowns lead to significant loss of revenue especially if it is during the rainy season when there is enough water to generate more power. In addition, employment of foreign firms and technicians is a drain on the plant. Similarly, the unit as indicated in Table 4.1 does not operate up to its design level due to faulty mechanical governor, and unavailability of spare parts. The factors such as the absence of a nearby workshop as well as lack of regular monitoring of the plant mechanical and electrical equipment led to low performance.

4.2.3 Tlokoeng (Mokhotlong) Mini Hydropower Station

The station is located in the eastern part of the country. The station used to supply an isolated load of Mokhotlong town. The hydro plant has two units of 460 and 210 kW and a backup system of two diesel units, a 200 kVA unit near the hydropower station and a 500 kVA diesel plant at Mokhotlong supplemented the station. Table 4.4 illustrates the performance of Tlokoeng hydropower up to the year 2000.

Table 4.4: Tlokoeng (Mokhotlong) mini-hydropower station

Item	1996	1997	1998	1999	2000	Average
Hydro turbines output (MWh	57	150	576	23	573	**276**
Diesel generator output (MWh)	510	318	795	1104	646	**675**
Percentage Hydro (%)	10	32	42	2	47	**27**
Annual duration Generation (hrs)	8859	8864	8857	8745	8667	**8798**
Energy output (MWh)	567	468	1371	1127	1219	**950**
Peak Demand (kW)	320	480	360	358	485	**401**
Using the load factor = (Energy/ (peak demand *Time)) (%) *(Designed 56.2%)*	20	11	43	36	29	**27**
Hydropower Technology Utilisation (Actual/designed energy utilised) (%)	17	14	42	34	37	**29**
Designed energy supply per annum (MWh)						**3298**

Source: LEC and Department of Energy-Lesotho

The station output varies from 567 MWh in 1996 to 1291 MWh in 2000, and the share of hydro was only 47 percent in 2000. Lowest contribution was of 2 percent in 1999 and the average of the stipulated period is only 27 percent. The station is suffered severe sedimentation as the tunnel leading to the turbines is unlined. In addition, the operators experienced several technical breakdowns due to pre-empted millennium uncertainties. The diesel generators supplied the balance of the power requirements. The power plant output is very low on average from 1996 to 2000 because several technical and non-technical problems. The location of Tlokoeng mini hydropower station is not easily accessible, hence makes it difficult for plant development and refurbishment due to lack of access roads. Also, the plant used designs and funding from France and it is difficult to obtain spares from either neighbouring countries or from French manufacturers (Lehloenya, 2002).

However, since November 2002, the station was shutdown because the 33 kV transmission line from Letseng-la-terai connecting the town of Mokhotlong has been faulty. The plan by the government is to use this plant to level the peak demands and so reduce power purchases from Muela hydropower plant and imports from Eskom. There are also ongoing discussions to allow interested investors to refurbish and run the plant as an independent power producer (IPP).

4.2.4 Semonkong Mini Hydropower Station

Semonkong mini-hydropower station is within in the mountainous part of the Maseru district. It supplies a nearby small town of Semonkong. The station started operating in 1989 and it is comparatively reliable. The station is the oldest and smallest of all the four mini hydropower stations as it has a capacity of only 180 kW, and a back up of 120 kVA diesel generator that is very useful during dry season. The Norwegian aid provided the funding and designs of the plant. Table 4.5 shows the general performance of the plant between 1996 and year 2000.

Table 4.5: Semonkong mini-hydropower station

Years	1996	1997	1998	1999	2000	Average
Hydro generation (MWh)	250	458	246	167	338	**292**
Diesel generation (MWh)	8	10	74	174	51	**63**
Percentage Hydro (%)	97	98	77	49	87	82
Peak demand (kW)	80	64	100	70	100	**83**
Annual duration Generation (hrs)	8716	8810	8649	8699	7939	**8563**
Using the load factor (Energy/ (peak demand *Time)) (%) *(Designed 34%)*	37	83	37	56	44	**51**
Hydropower Technology Utilisation (Actual/designed energy utilised) (%)	48	87	60	64	73	**66**
Designed energy supply per annum (MWh)						**536**

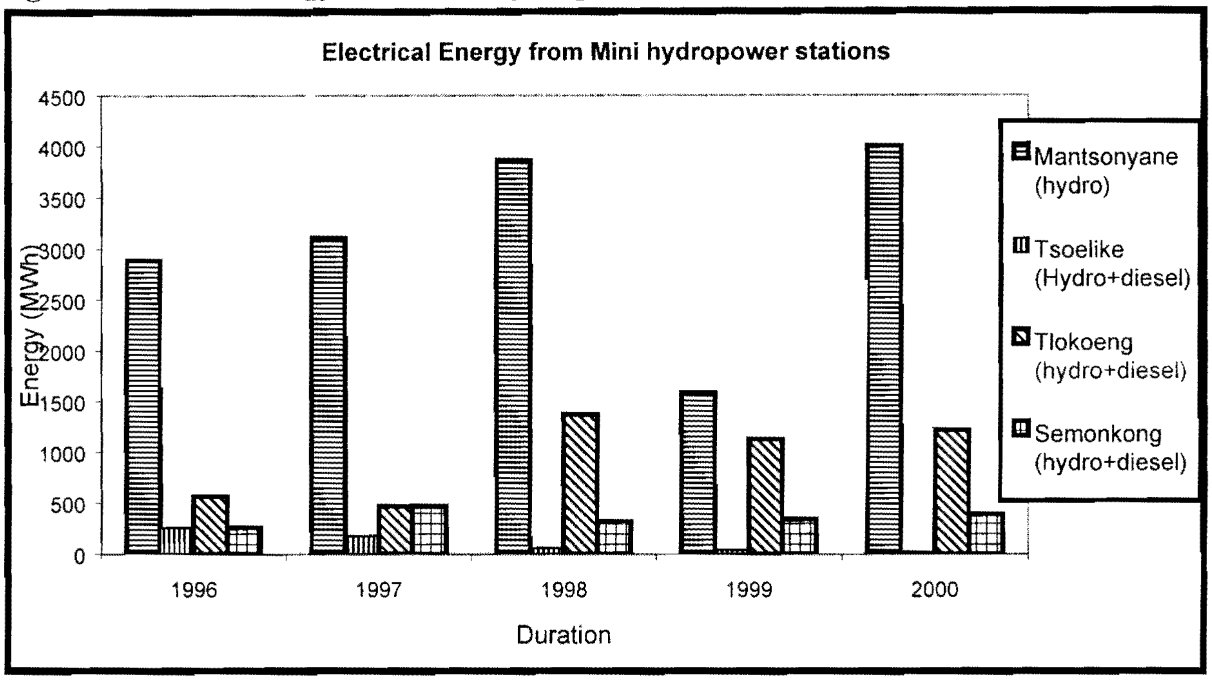
Source: LEC and Department of Energy-Lesotho

The plant capacity utilisation is about 66 percent and is fairly higher than the others and this is useful because it increases the reliability of supply to Semonkong, which has steady load averaging at 355 MWh. The hydro share of power generation was 82 percent between the five years specified, but generation from the diesel plant was about 50 percent in 1999 of drought in the country that year. The plant currently serves only 25 customers but there is potential to double the number of customers. The supply network consists of an 11 kV transmission line and low voltage distribution lines.

Initially, foreign engineers worked at the station but after commissioning, the plant is under the operations and maintenance of few local technicians who rely on guidance from the Engineering division at the headquarters of Lesotho Electricity Corporation. All the operators from all these mini hydropower stations received formal training from the technical institutions in Lesotho and additional external plus on site training (Lehloenya-LEC, 2002).

The general performance of the mini hydropower stations is not satisfactory because they are not operating at the design levels. Three of four are using diesel back-up generators more often than the hydro system. Figure 4.1 illustrates the comparative situation although the designs do not have same power output.

Figure 4.1: Total Energy from Mini hydropower stations 1996-2000



Source: Department of Energy-Lesotho and LEC

Mants'onyane mini hydropower seems to be performing comparatively well and it generates only with hydro. Conversely, Tsoelike mini hydropower is not generating up to its capacity level because Eskom, South Africa supplies most of the power demand through the cross-border connection. On the other side, the mini hydropower plants are experiencing several natural problems such as sedimentation. The other problems are lack of technical staff for immediate repairs as well as an inadequate supply of complementary spare parts. Appendix B provides a detailed performance of mini hydropower systems for the studied period.

4.3 Present Electrical Energy Sector Profile of Lesotho

The electricity production in the country is from hydropower plants and a backup system of imports from South African Eskom. Lesotho reduced its dependence on Eskom for electricity supply after the commissioning of Muela hydropower plant under Lesotho Highlands Development Authority (LHDA) that has a capacity of 72 MW in 1999. Before then, almost all the electricity imports were from Eskom, South Africa. The construction of the station follows recommendations from the Lesotho Energy Master Plan (LEMP) that emphasise the importance of utilising environmentally friendly indigenous energy resources in the country.

There is a plan to improve the plant capacity by a further 38 MW during the implementation of second phase of the Lesotho Highlands Water Project (LHWP). LHDA owns Muela hydropower plant and the transmission lines. Power from Muela hydropower connects to the national grid through 132 kV transmission line to Maputsoe industrial substation. The station also consists of a Muela Control Centre operating 24 hours above the underground powerhouse and the hydropower facility at Muela. LHDA also operates a 500 kW Katse mini-hydropower as a stand-by system for the daily activities within the dam. Table 4.6 shows some parameters of Muela hydropower plant.

Table 4.6: Characteristics of Muela hydropower station

Year of Construction	Rock	Dam Width (m)	Height (m)	Length (m)	Volume (m^3)	Net head (m)	Unit Capacity (MW)	No. of Turbines
1995 -1998	Sand stone	14	55	62	6,000,000	166	3 units × 24	3

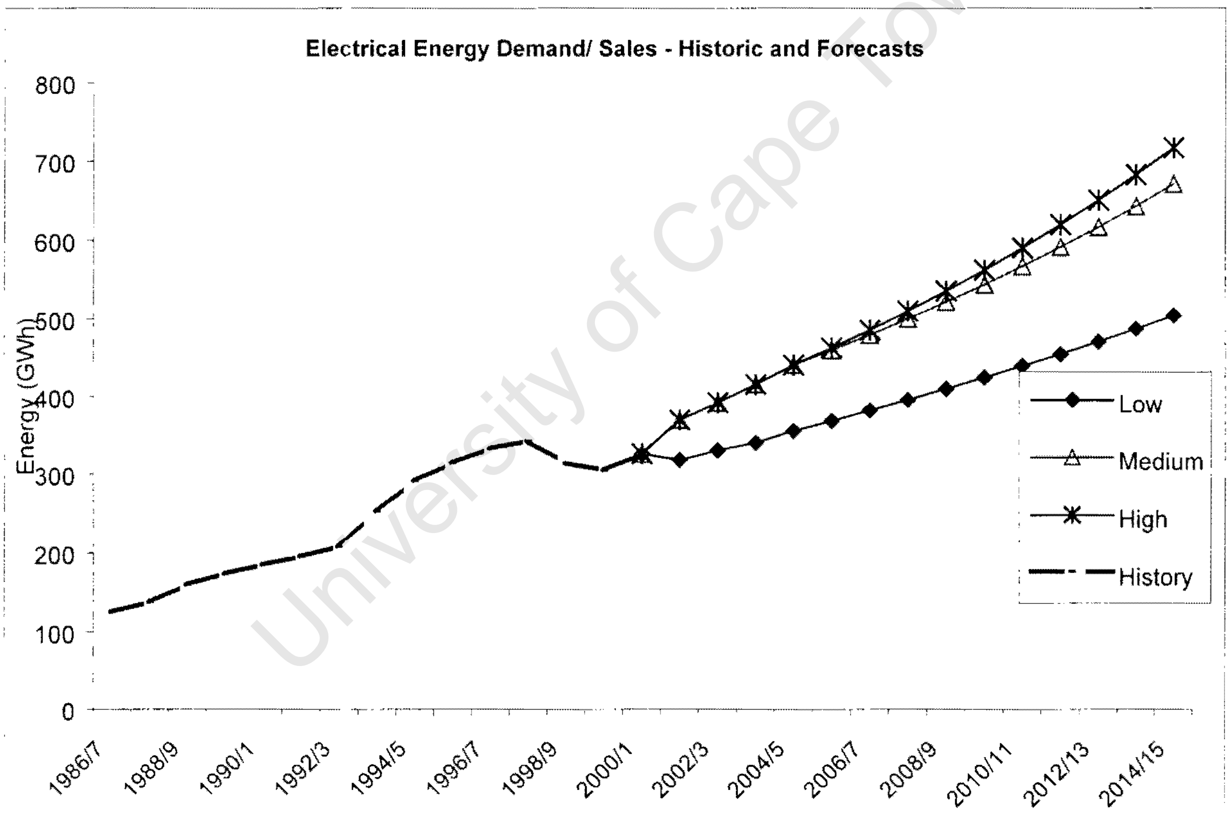
Source: Lesotho highlands Development Authority 2003

Lesotho Electricity Corporation (LEC) supplies electricity to the end-users through transmission and distributions lines operating at 132kV and below. In 2002, less than 7 percent of the households had access to the LEC network. There are on-going projects aimed at connecting 8000 households per annum with the long-term target connecting at least 35 percent of households by the year 2015 (Department of Energy, 2003). The electricity demand is growing rapidly; because of the important role electricity plays in improvement of livelihood and industrialisation of the country.

4.4 The Electrical Energy Demand

The load demand forecast shows scenarios of rapid increase in electrical energy demand based on the future economic and development prospects. The graph on figure 4.2 shows the Lesotho load forecasts with low, medium and high scenarios.

Figure 4.2: Electrical Energy Demand



Sources: Department of Energy-Lesotho and Swedpower, 1997; Lesotho Electricity Corporation, 2001, The historical trend and the future forecasts for electrical energy demand indicates a slight decrease on energy consumption during the fiscal year 1998/1999 and then an increase again in year 2000/2001. The decreases observed were primarily due to the completion of many activities of Lesotho Highlands Water Project (LHWP) with high-energy intensive operations.

The increase on energy demands shows that Lesotho will need more power generation capacity before the year 2010. The power demand forecast based on the peak load per annum follows the same trend as the energy demand. The peak demand in 2000 reached 74.4 MW and in 2001 and 2002, it was 86 MW and 92 MW respectively whereas the maximum generation capacity of the main power station, Muela is only 72 MW (Lesotho Electricity Corporation. 2003). The peak demands imply that within five years of commissioning the Muela hydropower station, Lesotho has to import substantial amount of electricity. The power generation sub-sector is highly technical and it requires technological knowledge at all levels. It is important for the country to review the previous and recent power station installations before engaging into power capacity expansion and more installations. The review will also assist the country to have a robust view and policy on transfer and acquisition of energy technologies.

4.5 The Lesotho Government and Technology Transfer

The government of Lesotho has a Ministry of Natural Resources that involves technical infrastructure departments including energy, water, and mining, meteorology and the newly established Department of Science and Technology. The Ministry also has responsibility over the utilities such as Lesotho Electricity Corporation for power generation, transmissions and distribution. The Ministry also has responsibility and direct linkage with the Lesotho Highlands Development Authority as a power generating entity. The Department of Energy through its power section coordinates large-scale energy technologies. The Department of Energy has the responsibility to install the power plants and operate them on a commercial basis. The power prices must be affordable and be able to service the capital and operational costs. The Lesotho Energy Master Plan (LEMP) encourages the government of Lesotho (GOL) to select hydropower technologies strategically and to implement those that are economically viable as compared to electricity imports (Department of Energy and GTZ, 1988).

The Department of Science and Technology has the responsibility for developing science and technology policy which may then lead to necessary regulations. Such policy can promote science and technology in order to create an enabling environment for technological development, which will contribute meaningfully to sustainable development. The department has to coordinate all the relevant stakeholders in order to draw a policy for all technology-related issues. The identified entities include Ministries of Local Government, of Agriculture, Forestry and Environment together with Ministry of Trade and Industry. The stakeholders also include the tertiary level educational institutions such as the National University of Lesotho and the Lerotholi Polytechnic as well as the NGOs. The Department of Science and Technology has a mandate to oversee and coordinate the activities within the sector. However, department was established in 1994, and it could not participate during the planning and construction of the stated power plant technology.

Lack of science and technology data in the country can lead to problems in the establishment and strengthen of scientific and technological infrastructure in the country. The other problems include poor facilities to undertake research and development, inadequate science and technology human capital as well as lack of commitment from the financiers and responsible institutions to allocate resources for RD&D activities. The Appropriate Technology section of the Ministry of Local Government coordinates small-scale technology designs and utilisation at household levels and the Department of Meteorology coordinates issues of technology transfer and climate change in collaboration with all the relevant departments.

The Ministry of Trade and Industry of Lesotho is in the process of establishing technology transfer policy and usually registers all foreign companies, firms and individuals who work and invest in the country. This Ministry encourages foreign companies to form joint ventures as subcontractors in the countries in order to enhance the technical capability. The ministry also advises other ministries to add technology transfer in the contract agreements with the foreign consultants, firms or individuals. However, at present there is no document or policy on the guidelines on technology transfer principles within Government ministries.

4.6 Concluding Remarks

The existing mini hydropower plants are not performing according to the design levels due to Civil and Electro-Mechanical problems associated with the technology. The plants were grants obtained from the foreign countries and companies as indicated. However, poor performance primarily illustrates that there was no proper transfer of technical expertise for the operations and maintenance especially after the departure of the foreign personnel. Poor performance also indicates the foreign based companies and consultants normally design the energy technology without thorough understanding of the local environment. The poor performance also indicates that the lack of involvement of local technicians who subsequently became the daily operators of the plant and technology.

In order to eliminate the situation in the future installations, it is advisable that all the power plants should have workshops with sufficient stock of spare parts. The workshop will enable the technicians to carry out basic repairs to equipment to ensure that the technology utilisation is consistent. The workshop will also reduce dependence on maintenance contractors to undertake repair and maintenance tasks. In addition, it will empower the local employees and entrepreneurs to maintain and operate energy technologies.

The Lesotho power demand is growing and in the year 2002, the peak demand reached 92 MW while electrical energy consumption was approximately 400 GWh. Therefore, the country has to expand and the existing generation capacity. However, there is no sufficient technological expertise in power-generating sector of Lesotho. The position of the country and the government regarding the approach of implementing high technical and energy intensive technologies was not specific. Apparently, the issue of technology transfer requires strategic approaches in order to optimise the benefits from such schemes as discussed in the previous chapters. The next chapter will look into a case of the Muela hydropower station installed between 1995 and 1999. The approach will test the integrated framework for technology transfer against the activities involved in order to determine if there was deliberate attempt to acquire and transfer technology to Lesotho people involved in the transfer process.

CHAPTER 5

FIELD WORK AND DATA COLLECTION

5.1 Introduction

The aim of this chapter is to provide the information and findings from the fieldwork carried out at Muela hydropower plant in Lesotho. The objective of the fieldwork was to collect information that will allow investigating if there was any transfer of technology and technical expertise to the people of Lesotho involved in the development and construction of the Lesotho Highlands Water Project (LHWP). The chapter present the data collected to identify the transferred technology using the suggested framework in Chapter 3. In addition, the framework will be used to determine the achievements, gaps and barriers occurred along the process of implementing Muela hydropower station with respect to technology transfer. The hydropower station is part of a joint venture project between the Kingdom of Lesotho and the Republic of South Africa.

5.2 Fieldwork

The fieldwork included collection of data and information from the relevant institutions and interviews of mainly the relevant personnel in these institutions on issues pertaining to the objectives of this work. In general, this exercise targeted the engineering staff and those responsible for decision making in their respective institutions. The formal interviews provided the information and data necessary for the analysis. The target group were the Lesotho Highlands Development Authority (LHDA), the power section of the Department of Energy and Lesotho Electricity Corporation. The information from the literature also supplemented the data. The questions followed the structure of the integrated framework for technology transfer. Specifically the interview targeted the following:

- The Head Engineer of Operations and Maintenance Group as well as the Operations Engineer in charge of operations and maintenance at Muela hydropower station.
- Chief Engineer and the Metering Manager of Lesotho Electricity Corporation
- Director and the Engineers at the Department of Energy-Lesotho

These people provided very useful fieldwork data of the project under study that supplemented the relevant documents and reports identified. The system of data gathering used was mainly an open ended question and answer method because of the spontaneous nature of the investigation in which questions are thought about based on responses given. However, as a guide the questions were framed to suit the demands of the integrated framework for technology transfer developed in this work and illustrated in Figure 3.6 in Chapter 3. (See Appendix A for a guide of questions used).

The survey started by determining the nature of the project with respect to the mechanisms and elements of technology transfer discussed in Chapter 2 and Chapter 3 respectively. The survey focused on the different stages identified in the framework and related activities to determine if there was any transfer of technology to the local staff involved in the project. The primary concern of the survey was the installation and operation of hydropower technology and transmission lines, though the project had different outputs. The survey also reviewed the information about the hydropower technologies in order to determine the specific technical areas that will compliment the integrated framework for technology transfer. The information collected is grouped according to the stages of the project.

5.3 The History of Muela Hydro Power Station and Assessment of Needs

Muela hydropower station is part of Phase 1A of the Lesotho Highlands Water Project (LHWP). LHWP is a bi-national and multipurpose development project that includes a number of dams and reservoirs, water transfer tunnels, construction of roads, pumping stations and a hydropower system. The LHWP is one of the unique engineering projects in Lesotho that is focussed on harnessing water resources from the highlands region of Lesotho resulting in joint benefits for both the Republic of South Africa (RSA) and the Kingdom of Lesotho. The idea of developing the LHWP emanated in 1930s when the government of South Africa intended to make use of the fresh water from Lesotho highlands. The preliminary plan included construction of big dams to transfer water into various industrial and important places in South Africa (LHDA, 2003).

5.3.1 The Preliminary Feasibility Studies

The preliminary studies started in the 1950s to determine the hydrological potential of the project to supply South Africa with water and thereafter, the feasibility studies of the economic viability of the project. However, there were neither progress nor follow-ups until the late 1960s when the government of Lesotho undertook another study that recommended construction of storage reservoirs at Oxbow and Pelaneng along the Malibamats'o River with water delivery tunnels into South Africa. In 1971, the government of Lesotho made another study by Bennie and Parterres that recommended a 94 meters high Pelaneng dam with a discharge of $8m^3/s$ into South Africa. In mid 1970s, South Africa appointed another consultants, Henry Olivier and Associates to study the water and power projections in the neighbouring countries particularly Lesotho as the immediate priority.

A joint preliminary feasibility study started in late 1970s when the two governments appointed their own consultants for the project respectively. The preliminary feasibility report produced in 1979 recommended a flow of $35m^3/s$ through a 102-km tunnel from Lesotho into RSA. The study also suggested the construction of five reservoirs, Oxbow, Pelaneng, Soai, Polihali and Taung all along the Malibamats'o and Senqu (Orange) River. The study further recommended hydropower generation in Lesotho as part of the entire project (LHDA, 2003).

5.3.2 The Detailed Feasibility Studies

In the early 1980s, both governments took a joint detailed feasibility study. The main objective of the study was to select the most acceptable project for both countries. The study also looked into the viability of the project concerning the engineering designs, social, legal and the environment aspects as well as the economic and the financial implications. The investigating team comprised of Lahmeyer MacDonald Consortium, on behalf of Lesotho while Oliver Shand Consortium on behalf of RSA (LHDA and Gibb Sogreah Joint Venture, 1988).

The detailed feasibility study recommended that the project could deliver water from phased construction of dams within the highlands of Lesotho into Vaal basin in South Africa. The study recommended a phased approach as the most economical way to implement the project. The study also recommended that the project should be based on analysis of technical, social, environmental impact assessment and economic investigations. In addition, they concluded that the project would be beneficial to both countries and contribute to their development priorities (LHDA and Gibb Sogreah, 1988).

5.3.3 The Plan for Implementation of Lesotho Highlands Water Project

The proposal to implement LHWP appears in a treaty signed on 24 October 1986 between the Governments of Lesotho and of the Republic of South Africa at Maseru, Lesotho. The signing agreement led to establishment of a Joint Permanent Technical Commission (JPTC) that initiated economic. technical and engineering studies. The main activities started in early 1990s. The LHWP redirect water flowing away through Senqu (Orange) River towards a more populated and industrialised Gauteng Province in South Africa using gravitational force as Senqu (Orange) river catchments is higher than Vaal River basin.

The project comprised of three main phases, namely Phase IA and IB, Phase II and finally Phase III. The signed treaty commits Republic South Africa and the Kingdom of Lesotho to implement phase 1A and 1B of the project and develop other phases in the later stage. Phase 1A include the main Katse dam and underground hydropower facility at Muela. Katse dam is 185 meters high, crest length of 710 meters, with reservoir capacity of 1950 million cubic metres and volume of 2300 million cubic meters. The project also included several civil works such as roads, water delivery tunnels, power supply facilities, construction camps and appurtenant works (LHDA Monthly Reports, 1995-1999).

The project has two primary goals, which emphasises the priorities of the stakeholders involved. The first goal is to deliver water from the LHWP dams into South Africa at a target of $70m^3/s$ by year 2020. The water discharge into South Africa was at $17m^3/s$ after commissioning of phase 1A in 1998. The second goal is to generate and supply electricity from the Muela hydropower plant from the bi-national project to address the Lesotho power demand and ensure security of energy supply. The hydropower generation component is mainly to utilise water transferred at different elevation of the Senqu (Orange) catchments and the Vaal basins.

Lesotho government also agreed to build the Muela hydropower in order to be self-sufficient in electrical energy supply as was proposed in the feasibility studies. Thereafter, the Trans-national companies brought in their technical expertise for planning and designing as part of the technology initiation stage. The government of Lesotho (GOL) pursued the proposal of electricity generation with the assistance of financiers and donors including the World Bank and international consultant (Hoohlo et al., 2002). Prior and during the construction of the phase 1A of LHWP, Eskom was supplying more than 95 percent of electricity used in Lesotho. However, since then the demand of the country was high because of industrialisation and other requirements for electricity in Lesotho were already higher than what was supplied, the country supported the project. Also, the government of Lesotho was concerned with energy security and having an indigenous supply was found acceptable. In addition, the government anticipated that the share of the construction sector to the GDP would substantially increase as result of the construction phase of the project. Moreover, the government projected increase in local labour during the construction and operational stages of the project. All these factors influenced the government's support for the initiation of the project.

5.3.4 Preliminary Studies before Construction and Installation of Hydropower Station

The initial role of LHDA was to oversee the construction and installation of Muela hydropower facility on behalf of the GOL. In addition, LHDA has legal responsibility to generate, operate and maintain the proposed hydropower plant. The consultant group, Gibbs Sogreah Joint Venture (GSJV) carried out the hydropower design contract on behalf of LHDA while the European Development Fund financed the activity.

The engineering consulting services were in two main stages. The first stage studies were on conceptual design and optimisation, and the next stage was on tender design and documents. The studies commenced in 1987 and on the hydropower components, the preliminary activities included the following tasks:

- Design and costs for alternative hydropower plants
- Services related to first stage on geotechnical investigations
- Comparison of alternative generation plans
- Re-optimisation of project components

On the other hand, the second stage studies were on tender design and documents. The consultants prepared the following technical notes shown in Table 5.1.

Table 5.1: LHDA Technical Notes

Technical Note	Topic
A	Review of Hydrology
B	System Yield Analysis
C	Preliminary Screening of Hydropower Options
D	System Reliability and stand-by Provisions
E	Reservoir Simulation and Power Generation Models
F	Transmission Systems
G	Engineering Review of Selected Hydropower Options
H	Economic Comparison of Selected Hydropower Options
I	Re-Optimisation of Overall scheme
J	Water Only scheme – Nqoe Dam
K	Verification of Operating Characteristics of the Recommended Scheme

Source: LHDA and Gibbs Sogreah Joint Venture, 1988

The objective of the second stage of the studies was to optimise the entire LHWP project before detailed designs of phase 1A components. The optimisation of the project was a primary objective of development for Lesotho within all the mentioned phases. The other objective of optimisation was to maximise the economic return of the hydropower project in Lesotho. The optimisation of the overall project was to provide the essential data for the hydropower component through:

- The constant availability of water on a monthly basis
- The operating level of the Katse reservoir
- The size and alignment of the transfer tunnel
- The power generation model developed to simulate the daily operation of the transfer tunnel, headpond, hydropower plant as well as tailpond and delivery tunnel.

5.4 Theoretical Background of Hydropower Technology

A brief background on hydropower is included, as it will assist the understanding of the analysis that followed. Countries with abundant hydro resources normally opt for storage hydropower plants because they can store water during summer rains and use it during peak demands in winter when needed most. Hydroelectric power plants have shortest start-up times as compared to other types of power plants such as coal-fired power plants.

5.4.1 The Different Arrangements of Hydropower Facilities

The first phase of the LHWP involved several activities including constructions of the Katse dam, the Muela dam and underground hydropower facility as well as water transfer tunnel. Practically, the criteria for implementation of hydropower technology stations vary from identification of suitable site for the plant to the construction of the storage dam. The identification of site depends on the geographic location and technical factors that determine optimum harnessing of power from the freely flowing water, the discharge and size of the head as well as possible losses and environmental factors. The criteria for implementation also depend on the particular type of system such as storage type, pure pump-turbine or mixed pump-turbine technology (Webster, 1999).

Usually, storage power plants use a portion of water immediately, and the remaining stored water in the reservoir can be later used for additional pumping plants. The run-off-river plants with weirs can be categorised as storage power plants. The water is stored at a higher elevation and falls through gravity to drive the turbines that is at a lower elevation. Water from the turbine can be used for other purposes downstream while in some cases if the head and discharge have sufficient power another hydropower system can be installed downstream as it happens in countries such as Norway. The Muela hydropower system uses similar arrangements. The storage power plants supply the base load if water upstream is available.

The pure pump-turbine power plants use both the pump and turbine modes with storage and reservoirs. In these power plants, the pump and turbines always have same storage at higher elevation and reservoirs at lower elevation because water drives turbines through gravity during the turbine mode. Conversely, the system pumps water from the lower elevation reservoir into to the storage at high elevation during the pump mode. The turbine modes operate when energy prices are high and at peak loads. Conversely, the pump modes work at night after peak hours and during non-working days, while the prices of electricity are low especially where the 'Time-of-Use' (TOU) tariffs are applicable. The pumped storage arrangements belong to the category of pump-turbine plants. The arrangement differ from the storage systems because it has the turbine mode and the pump mode and the plant requires building of storage facilities at higher elevation and at lower elevation. In addition, they are essentially applicable to address short-term peak demands and to level the load curves.

The third option is of mixed power plants although not commonly used due to complications involved. This arrangement also requires more water storage facilities than the previously discussed. The system comprises of a combination of a storage power and a pure pump-turbine power facility.

5.4.2 The Different Types of Turbines and Generators

In addition to the characteristics of the site and the type of facility, the selection of hydropower technologies depends on the design of the equipment. The choices of equipment include the inlet valve of the tunnel, type of turbine, the size and type of generator, the size of transformer, and the bus bar. Equipment selection requires precise analysis in order to achieve optimal plant design. The selection of the hydropower turbine depends on the available head size H_n (m) as well as the rated power output P_t (MW) from the power plant. In addition to the mentioned factors, the selection depends on the rated discharge Q_n (m^3/s) and the rated speed n_n (rpm). The speed of turbine also differs according to the power-speed characteristic and the efficient-speed characteristic. Thus, the different groups of turbines tend to run efficiently at certain speed and head sizes. The fast turbines are preferable for small heads and large discharges while the slow turbines are more efficient for large hydraulic heights and small discharges. Therefore, selection of turbines depends on high, medium and low head. The types of turbines can be either impulse or reaction turbines or a combination of the two. The Table 5.2 below illustrates the two types along with their characteristics.

Table 5.2: Different Groups of Turbines and Ranges of Heads

Turbine Runner	**Head Pressure**		
	High (350-1800m)	Medium (40-700m)	Low (5-80m)
Impulse	• Pelton • Turgo • Multi-jet Pelton	• Crossflow • Turgo • Multi-jet Pelton	• Crossflow
Reaction		• Francis • Pump-as-Turbine (PAT)	• Propeller • Kaplan

Source: Harvey, 1993; Webster, 1999.

The impulse turbines experience pressure on either side of the runner while for reaction turbines, the pressure drops is across the runner. The impulse turbines are cheaper as compared to the reaction turbines because they do not involve special casing or engineering clearances. In addition, the impulse turbines have the following advantages over the reaction turbines.

- More tolerant to sand and particles in the water
- Easy access to working components
- Easy to maintain and fabricate
- Less vulnerable towards cavitations
- Have flatter efficiency curves especially when built with a flow control device

On the other hand, the reaction turbines rotate faster than the impulse under the same head and flow conditions. They can be coupled to an alternator without using a speed increasing device and hence less expensive (Harvey, 1993). The installation of turbines can either be in a vertical or horizontal set-up, which will result in different characteristics.

The type and group of installed turbines at Muela are horizontal Francis types as the head size of the plant is medium. The advantages of reaction turbines already described played an influential role in the selection of turbine installed. These are large vertical Francis turbines with Heads ranging from 50 m to 700m. It should be noted that the Itaipu hydropower plant in Brazil which is currently the largest hydropower in the world operating with 18 units of 700 MW each, and total capacity of 12 600 MW uses this type of turbine. The Three Gorges Project in China is going to operate 26 units of 700 MW with total capacity of 18 200 MW and annual energy output of 85 TWh when operational in 2009 will be using this type as well and so will be the largest hydropower plant in the world when completed (Webster et al., 1999). Table 5.3 outlines the factors that influence the criteria for selection of turbines and generators.

Table 5.3: Theoretical criteria for selection of turbines and generators

Selection Criterion of Turbines	Selection Criterion for Generators
Choice of the turbine outputs for total power P_t, rated head H_n as well as maximum head H_{max} and minimum head H_{min}.	Choice of rated and maximum apparent power at rated power factor, for over and under exited models.
Choice of the rated and specific turbine speeds (n_n and n_q), and analysis of the runaway speed (n_r).	Choice of rated generator voltage with permissible voltage range.
Cavitation behaviour and setting of turbine spiral case, choice of ρ value and permissible cavitations damage.	Choice of permissible temperature rises for stator and rotor windings as well as the Cooling systems
Choice of the operating ranges, such as power, net head and duration of operation.	Analysis of rotor stress at runaway speed
Turbine efficiency and choice of the weighting factors.	Choices of generator utilisation factor (Esson Coefficient).
Hydraulic steady and transient state conditions.	Choice for moment of inertia in accordance with the turbine regulation conditions.
Draft tube and spiral-case pressure fluctuations and power swings.	Bearings and shaft arrangements, first critical speed.
Analysis of the main design requirements such as geometrical dimensions, material quality, definition of deflection and fatigue limits.	Choice of reactance and time constants (Synchronous, transient, and sub-transient) in the direct and quadrature axes.
Model test for turbine according to authoritative standards; determination the prototype performance from model acceptance test, taking scale effects consideration.	Behaviour of the generator-turbine set; vibration and noise levels, choice of the monitoring equipment for the air gap, partial discharge, and vibrations.
Analysis of the resonance frequency between penstock, turbine, generator and network.	Synchronous condenser operation if any
Maximising the reliability and serviceability of the turbine components.	Braking system.
Main design of the inlet valve, including rated diameter, design and test heads, rated and maximum discharges, breakdown discharges.	Excitation system, cooling, voltage exciter response.
Transport constraints for turbine and inlet valve components.	Transport constraints for generator components.
Manufacturing and erection facility for turbine and inlet valve components.	Manufacturing and erection facility for generator components.

Sources: Harvey, 1993 and Webster, 1999.

5.4.3 The Different Hydropower Transformers

Criteria for purchasing of power transformer depends on the following factors:

- Transportation means from the manufacturing firm to the installation site
- Easiness of installing the transformers in caverns or in the open space
- Short-circuit power of the high voltage network over a long time
- Maximum voltage limits of the high voltage network
- Possible means of handling the high voltage variations by installing a regulator on a generator.

Three-phase unit is more advantageous because of the cost factor and they require less space as compared to the single phase but it is less difficult to transport single-phase transformers. However, single-phase transformers are necessary as stand-by to ensure continued energy supply.

5.5 Technology Selection Installation of Muela Hydropower Facility

The process of selecting technology started with consideration of two dams with different features. The preliminary studies proposed detailed analysis of the two sites for constructing the dams, Muela and Tlhaka. LHDA employed GIBBS consultants for further technology assessment. The consultants considered the two sites because of their different geotechnical features. The dams differed in design, concept, and scale as well as in costs. Preliminary design showed that Muela would be a concrete gravity-arch dam while Tlhaka would be an earth core rock-fill dam.

5.5.1 Selection of Muela hydropower

Since the hydropower station was to be along the tunnel to South Africa, optimisation of the hydraulic passageways was the basis for the analysis of mechanical works. In addition, the size and diameter of the tunnel became one of the optimised parameters that determined the power output in the station. Generally, the basis for selection of hydropower technology was on installation capacity, turbine ratings, generators and the global unit characteristics acquired elsewhere. The analysis for selection of hydropower technology also considered. The net head influences the overall performance and characteristics of the hydropower systems. Table 5.4 gives an impact of varying the turbine discharge (m^3/sec), turbine and overall efficiency (%) and power output (MW) of the plant with respect to net head (m).

Table 5.4: Plant machine characteristics for different levels of net head

Net head (m)	Turbine discharge (max gate opening) (m^3/s)	Turbine efficiency (%)	Generator efficiency at 0.95 power factor (%)	Overall efficiency (%)	Maximum station output (MW)
196	30.93	92.5	97.1	89.0	52.8
216	32.91	93.9	97.5	90.8	63.2
236	34.79	94.1	97.9	91.1	73.2
253	36.27	93.5	98.1	90.8	81.6
270	37.61	92.8	98.2	90.2	89.7

Source: LHDA and Gibb Sogreah, 1988

The analysis of all the scenarios is subject to continuous generation of 89.9 MW at a power factor of 0.85, with overall efficiency allowance of 1% for transformer losses and station consumption. Table 5.5 also shows the headlosses in hydropower plant components.

Table 5.5: Headlosses in Hydropower Plant Components

Component	Diameter (m)	Length (m)	Headloss (m) at nominal discharge of $35m^3/s$
Transfer tunnel	4.95	45 000	33.9
High level penstock	3.35	29	0.2
Penstock guard valve	2.5	-	0.4
Vertical penstock	2.5	260	4.1
Turbine Branches - Inlet	1.45	29	1.4
Turbine Branches - Outlet	2.4	50	0.1
Tailrace tunnel	4.1	1 460	2.3
Total			**42.4**

Source: LHDA and Gibb Sogreah, 1988.

Table 5.5 primarily shows that the major losses are due to the water transfer tunnel from Katse intake to the penstock above the powerhouse. The dimensions of water transfer tunnel such as type of tunnel, the diameter and length and material used have major effect on the ultimate head losses. The penstock also contributes significantly to head losses at Muela hydropower plant. Table 5.6 summarises the different characteristics for hydropower designs for Muela and Tlhaka sites respectively.

Table 5.6: Comparative Characteristics of Muela and Tlhaka

OPTION	**Muela Dam site**			**Tlhaka Dam site**		
Suggested Capacity (MW)	60	70	80	60	70	80
Turbines (Francis)						
Maximum net head $\mathbf{H_{max}}$ (m)	264	264	264	264	264	264
Rated net head $\mathbf{H_n}$, (m)	**243**	**243**	**243**	**246**	**246**	**246**
Minimum net head, $\mathbf{H_{min}}$ (m)	**200**	**200**	**200**	**204**	**204**	**204**
Turbine unit output $\mathbf{P_t}$, (kW)	20 830	24 300	27 770	20830	24 300	27 770
Rated unit discharge (m^3/sec)	**9.73**	**11.37**	**12.97**	**9.60**	**11.22**	**12.80**
Specific speed n_s (metric) $\mathbf{n_n}$ and $\mathbf{n_q}$	**131.5**	**142**	**152**	**129.5**	**140**	**149.6**
Nominal unit speed n (rpm)	750	750	750	750	750	750
Full load efficiency (%)	90	90	90	90	90	90
Runner exit diameter (m)	**1.065**	**1.127**	**1.180**	**1.065**	**1.125**	**1.175**
Available submergence (1 unit only) (m)	**8.95**	**8.95**	**8.95**	**8.75**	**8.75**	**8.75**
Generators						
Rated output (Power factor = 0.85) (MVA)	24	28	32	24	28	32
Rated Voltage (kV)	11	11	11	11	11	11
Unit Global Characteristics						
Starting up time ***Tm*** (sec)	4.0	4.0	4.0	4.0	4.0	4.0
Actual GD^2 (generator inertia) of rotating parts (tm^2)	54.2	63.4	72.8	54.2	63.4	72.8
Actual GD^2 /Natural GD^2	1.42	1.37	1.33	1.42	1.37	1.33
Runaway speed of Unit n_r (rpm)	**1 417**	**1 449**	**1 259**	**1 400**	**1 436**	**1 450**
Runaway coefficient	**1.89**	**1.93**	**1.95**	**1.87**	**1.91**	**1.93**

Source: LHDA and Gibb Sogreah, 1988

Apparently, Muela has higher rated unit discharge and specific speed than Tlhaka. In addition, the runner exit diameter and the available submergence are larger for Muela. The generator characteristics also indicate that Muela would experience higher runaway speed and coefficient. The upstream reservoir has an operating range in the excess of 60 meters and the losses in the tunnel are quite significant. The dams also differed according to sediment loads where Muela estimated to be between 10 and 15 grams per litre, while Tlhaka estimated to be 10 grams per litre of sediment loads. Moreover, the feasibility studies and planning envisaged fewer technical problems at Muela as a site than at Tlhaka. Geologically, the sandstone at Muela site appeared to be considerably hard and massive as compared to the basalt rock at Tlhaka. In addition, the planning activities envisaged the small scale of works and flood diversion requirements were not significantly necessary. The factors also led to selection of Francis turbines that are suitable for large range of heads.

5.5.2 Selection of Hydropower Technology on Economic Aspects

The final decision for selection of Muela was because it was cheaper compared to Tlhaka, as the initial cost estimations for the dams were R31.07million and R81.65million respectively (LHDA and Gibb Sogreah, 1988). Subsequently, Muela site option was recommended with installed capacity of 80 MW. However, the output of 72 MW using three units of 24 MW each with 10 percent allowance for technical losses as the plant has full load efficiency of 90 percent (see Table 5.6). Therefore, the plant has a potential of generating 80 MW at the high end of the operating head. The project implementation started in 1995 and the plan started operating towards the end of 1998. The inception phase took 3 to 6 months. The first unit started to generate electricity in August 1998 and the last unit in January 1999. The plant also supplied more than 330 GWh during the first year of operation, (August 1998 to July 1999). There is a plan to increase the capacity to 110 MW in phase II of the LHWP (LHDA, 2003).

Muela is the biggest hydropower station and the main source of electricity in Lesotho. It comprises an underground hydropower facility at the end of a 45-km long with diameter of 4.35m concrete headrace tunnel from Katse dam. Appendix C illustrates the schematic diagrams of the Muela hydropower facility. Muela hydropower station also operate as a multipurpose development scheme that includes a dam and a reservoir, delivery tunnel and it discharges some of the water into Lesotho for other purposes before flowing into the Vaal basin in South Africa.

There is a contract for the annual water discharges under the agreement between the governments of Lesotho and South Africa. LHDA also has to meet the annual water transfer obligations stipulated in the treaty. However, LHDA has the full flexibility to meet the discharges per annum because the important factor is the quantity of water delivered per annum rather than the unit discharge (Hoohlo et al., 2002). The actual distribution of electricity requirement relies on LHDA, based on the assessment of the two-day load forecasts from Lesotho Electricity Corporation (LEC)

The construction and installation of Muela hydropower proceeded in parallel with the building of the Muela Control Centre (MCC) located within the site and the National Control Centre (NCC) situated at Maseru. LEC has responsibility to operate NCC, which is controlling the entire national grid. In addition, LEC has responsibility of maintenance of a 132 kV transmission line between the station and the substation at Maputsoe industrial area. LHDA operates MCC and has responsibility to control the power output at Muela. MCC includes the infrastructure for hydropower and responsible for water transferred to South Africa. The aim of MCC is to maximise the energy converted and to optimise, the operation of the hydropower plant in order to reduce the electricity imports from Eskom in South Africa.

5.6 The Creation of Enabling Environment and Technology Imports

Creation of an enabling environment includes access to financing, insurance, and availability of standards, highly trained manpower, stable macro-environment and other factors as shown in Figure 3.6. This section present the observed measures for creation of enabling environment for technology transfer within the case study.

5.6.1 Access to Funding for Muela Hydropower

The management held a donor conference before construction and installation of the plant in order to ensure availability of funds. The main financial commitments were in a form of grants, loans, export credits and risk capitals Table 5.7 indicates all the funding sources and the respective component funded.

Table 5.7: Funding Sources for Muela Hydropower plant

Source of Fund	Type of Financing	Million (Rand)	Task Financed
Dredsner Bank (Germany)	Export credit	30.2	Underground Powerhouse
Banque Nationale de Paris (France)	Export credit	57.8	Underground Powerhouse
Hill Samuel ABN AMRO (UK)	Export credit	12.8	Underground Powerhouse
Lesotho Bank	Commercial	40	Underground Powerhouse
Ned Bank Lesotho	Commercial	80	Underground Powerhouse
Development Bank of Southern Africa	Concessionary Loan	45	Underground Powerhouse, Muela dam, Construction Insurance, Reinstatement and enhancement projects
European Investment Bank	Concessionary Loan – Risk Capital	69.5	Muela Dam
European Investment Bank	Own resources Commercial	23.9	Switchgear and Transformers
European Union	Grant	273	Muela Dam, Underground Powerhouse Supervision Training
Swedish Government	Grant	59.3	Turbines and Generators
Svenska Handelsbanken (Sweden)	Export Credit	59.3	Turbines and Generators
Department of International Development (UK)	Grant	39.1	Turbines and Generators
West Merchant Bank	Export Credit	29.2	Turbines and Generators
Banque National de Paris (France)	Export Credit	23.5	Transmission lines
Government of France	Concessionary Treasury Loan	15.7	Transmission lines
Government of Lesotho	Direct Contribution	100	Administration
SEB (Sweden)	Export Credit	30	National Control Centre SCADA
Total		**988.3**	

Source: LHDA, 2003

The total costs of Muela were approximately R1 billion of which one third was in a form of grants. The principal loan is repayable over the first 12 years after commissioning, thus by the year 2011. The lifetime of the plant is considerably longer than that repayment period and there are efforts by the Government of Lesotho to refinance the loans within the stipulated duration. The immediate repayment will reduce the pressure on the cash flow of the plant operations. Government of Lesotho is currently considering several different refinancing models.

5.6.2 Access to Insurance for Muela Hydropower

There are three main categories of insurance involved at Muela Hydropower plant. The plant had insurance coverage during the construction stage and every contractor involved had an obligation to have insurance before signing any contract. The second insurance is for operation at breakdowns that may occur. Therefore, all the operational activities are under insurance. The other insurance within the plant is for losses that may occur due to planned and unplanned outages. Since the plant is less than five years old, there is an insurance agreement made with the maintenance contractors for the first 6 years after commissioning. In view of the agreement, the contractors always available on call at any time to rectify any technical problems on installed equipment or the way the plant is supposed to run.

5.6.3 Training and Capacity Building of LHDA Counterparts

The external formal training lasted approximately for 20 months. It mainly took place at Eskom, South Africa, Kafue Gorge Hydropower Training Centre in Zambia and in the Republic of Ireland. The training involved more than 30 technical personnel, made up of Management staff, Technicians and Operators. The first training lasted 12 months and started in Ireland towards late 1996 with 28 technicians and operators. Thereafter, all the technicians came to South Africa for 6 months for further training while the operators remained in Ireland for training on hydropower development. Thereafter, all the operators and technicians went for training in Zambia for four months. Simultaneously, the middle and top management assigned at the plant went for training in Eskom, South Africa to enhance their engineering management skills. The technical personnel obtained formal training on Mechanical and Electrical Engineering from local institutions and outside the country. They also gained hands-on training on operations and maintenance of hydropower technologies. Moreover, the management gained some training in Sweden for hydropower development at postgraduate level.

Training is an ongoing and continuous programme for the development and enhancement of the staff. The programmes involve working closely with technicians and engineers from Eskom South Africa and the sub region. The assigned technicians regularly visit the Drakensburg pumped storage facility in Kwazulu Natal, South Africa to gain experience of some important functions of the hydropower systems. Similarly, the Eskom technicians visit Muela hydropower facility for their own benefit and assistance. Therefore, there was an ongoing technology knowledge exchange and skills enhancement for Muela technical personnel. The technical exchanges and regular visits between the hydropower facilities provide essential basis for collaborative research and development that can be beneficial for the technical personnel within the LHDA, Trans-Caledon Technical Authority (TCTA) and Eskom. The exchange of personnel component forms an important part of the conceptual framework for technology transfer. In addition, the management normally encourages the operation and maintenance staff to prepare papers and attend relevant forums, conferences and seminars. The continuous involvement in these activities improves the knowledge, experience, rewards and recognition of engineers and technicians substantially.

The level of technical skills at Muela hydropower station increased substantially as compared to the previous projects of similar nature such as the previously installed mini hydropower plants. In addition, Manitoba Hydro of Canada conducted a comprehensive skills and level of technical knowledge assessment before the commissioning of the station.

5.7 The Installation of Muela Hydropower Plant

This section discusses the installed components and areas where it was possible to transfer technical skills from South Africa and expatriates from other countries to the people of Lesotho. This section also reviews the areas of construction and installation where South Africans shared their skills and knowledge to the people from Lesotho in addition to the activities during the pre-feasibility and feasibility studies. Approximately six countries including Lesotho and South Africa participated during the construction, installation and initial operations of the plant. Table 5.8 shows the main activities and the leading contractors that undertook the construction.

Table 5.8: Main activities and the leading contractors for each component

Contract Main Activity	Contractors Names	Country of Origin
129A-Underground Powerhouse	Muela hydropower contractors (MHPC) • Spie Batignolles (leading contractor) • Balfour Bealtty • Ed Zublin • Campenon Bernade	 France UK Germany France
129B - Muela Dam	Muela hydropower contractors (MHPC)	Same as above
134-Turbines and Generators	• ABB Generation • Kvearner Boving	Sweden UK
135-Switchgear and Transformers	ABB	Germany
136-Transmission Line 132kV	NORELEC	France

Source: LHDA Monthly Reports, 1995-1999

The consortium of contractors made of Muela Hydropower Contractors (MHPC) and they did underground powerhouse while ABB Power Tech Transmission from Germany dominated the power transmission works. The other leading consortium on installation of turbines was ABB KBO, which consisted of companies from Sweden and United Kingdom. The whole consortium of major contractors included some South African based subcontractors and many individuals from South Africa with technical skills (Hoohlo et al., 2002). In addition to the leading contractors, were several subcontractors that formed partnerships with South African based contractors and few Lesotho based companies. The major subcontractors were mainly from European countries with Lahmeyer International GmbH and Molt Macdonald International Ltd in association with ABCC- Lesotho leading the sub-sector. Subcontracting as mentioned previously is another mechanism of technology transfer where the recipient receives permission to operate according to the guidelines and specifications under the brand name of the main company. In some cases, the recipient uses well-known trade name as subcontractor in order to gain recognition especially when competition for services is high. Table 5.9 below illustrates the subcontractors involved and their respective tasks.

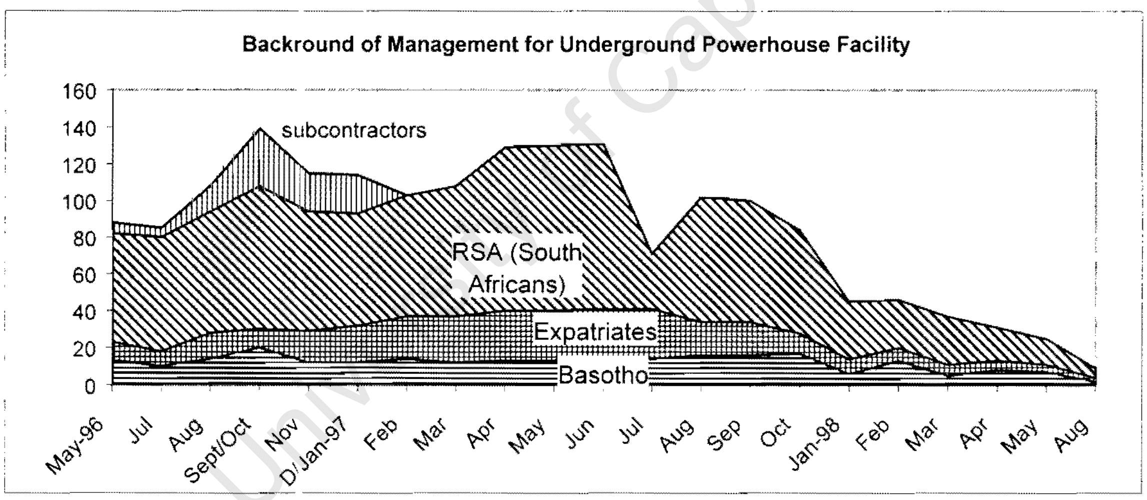
Table 5.9: Subcontractors and their respective main activities

Subcontractor	***Activity***
LTA LTD	Nearby Clinic construction
GEC Althon Neyupt	-Principal Mechanical and electrical -Penstock steel linings -Tailrace outfall gate, bypass steel lining
Otis	-Powerhouse lift
Condra	-Powerhouse (EOT) Crane
HHK	-Earthing
KAREENA	-Slip forming, lifts and cables shaft
Keitz and Geithner	-Plumbing and sanitary
Kvaener Boving	-Bypass valves and ancillaries
Torrex	-Upstream surge shaft
LTA construction LTD	-Operating Building
Raubex	-Quarry Operation
Steward Scott	-Mechanical and electrical designs
SACES	-Drilling and Grounding

Source: LHDA Monthly Reports, 1995-1999

The foreign experts and foreign companies shared and exchanged their technological knowledge with South Africans while Lesotho people learnt from both. On the other hand, the component of personnel at management level for installation and initial operations comprised of the expatriates, South Africans as well as few subcontractors with different skills and technical expertise. Lesotho people participated in the process as counterparts to the foreigners in order to acquire necessary skills to manage, maintain and operate the plant according to its designs. Figure 5.1 below illustrates the background of management involved during the installations and initial operations with time.

Figure 5.1: The Management during Installations and Initial Operations



Source: LHDA Monthly Reports, 1995-1999

Table 5.10 provides a summary of personnel involved during the construction of the project. Appendix D also illustrates the detailed works and the involvement of Lesotho people during the installations.

Table 5.10: Personnel Involved during Construction of Muela Hydropower Plant

Management Level	***Percentage (%)***			
Contract main Activity	**Subcontractors**	**Lesotho People**	**Expatriates**	**South Africans**
129A- Underground Powerhouse	17	12	15	56
129B- Muela Dam	32	11	10	47
134- Turbines and Generators	-	33	67	-
135 &136- Switchgear and Transformers and Transmission line		33	67	-

Labour Skills Level	***Percentage (%)***			
Contract	**Subcontractors**	**Skilled**	**Semi-skilled**	**Unskilled**
129A Underground Powerhouse	19	9	28	44
129B Muela Dam	47	4	13	36
134 Turbines and Generators	45	20	11	25
135 &136 Switchgear and Transformers and Transmission line	37	21	15	27

Source: LHDA Monthly Reports, 1995-1999

The summary on table 5.10 follows the data and fieldwork information under Appendix D. The information shows that the number of Lesotho people involved in the management of Muela hydropower station during the construction and installation was low as compared to other nationals and the involved subcontractors.

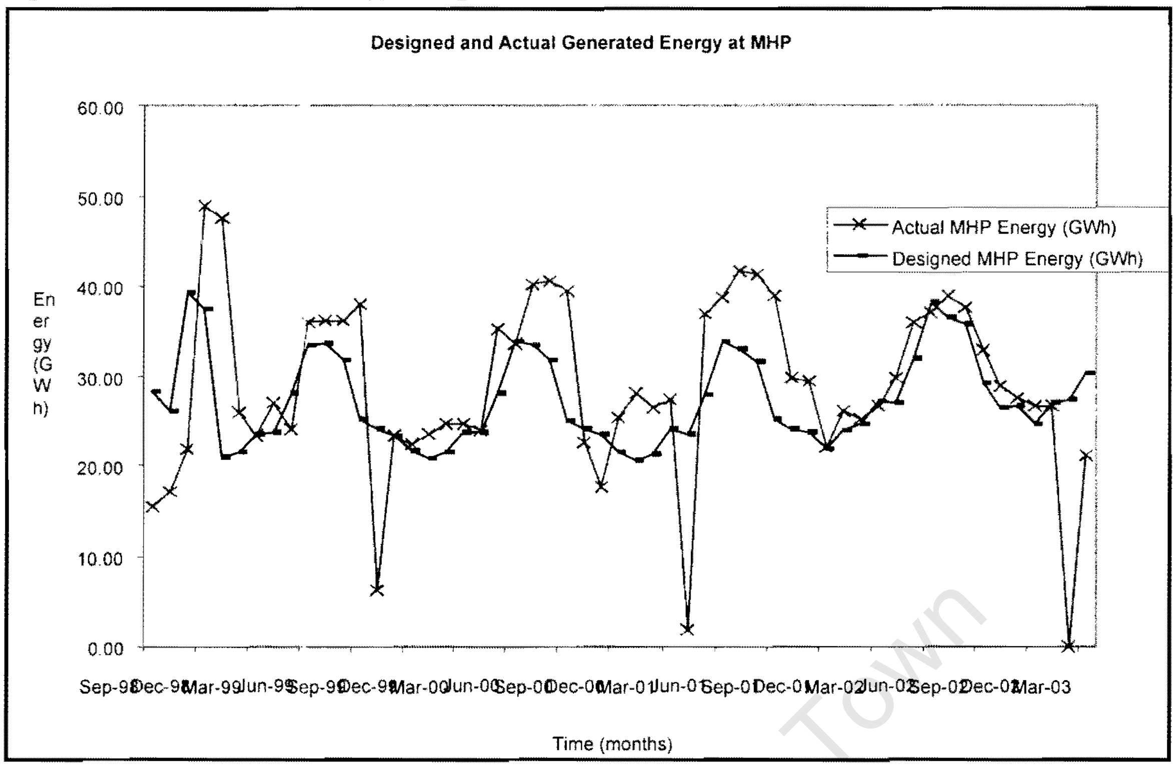
It is evident that people of Lesotho had insufficient managerial and technical know as they shared the least portion of the work while the South Africans occupied larger portion comparatively. Therefore, there was technology transfer from the foreign companies and personnel to ordinary Lesotho people. It is also evident that the transferred skills were mainly from South Africa as it is another partner and beneficial of the bi-national joint venture of Lesotho Highlands Water Project. The subcontractors from foreign companies also transferred their skills to Lesotho people as they participated in the process.

Low participation of Lesotho people signifies that the technical expertise and required skills were limited among the people of Lesotho. Consequently, the country and LHDA as government agency relied on the foreign enterprises that did not assisted the achievement of the main goal of sustainable development for Lesotho as recipients of the hydropower technology. On the other hand, the main stakeholders of bi-national LHWP joint venture from South Africa also participated effectively as they occupied larger portion of personnel within the technical and engineering management teams. The limited management skills within the country also created opportunities for the international companies who also contributed effectively by transferring such technical skills to Lesotho people. As mentioned in the previous section, some LHDA personnel went for training prior and during the installation processes. The purpose of training was to ensure transfer of technical knowledge and engineering management skills because the technical issues require trainable and conversant counterparts.

5.8 The Operational Performance of Muela Hydropower Station

Electricity generated at Muela since August 1998 to March 2003 is illustrated in Figure 5.2. The actual capacity utilisation against the designed or installed capacity is an indicator of technology absorption and assimilation by the operators.

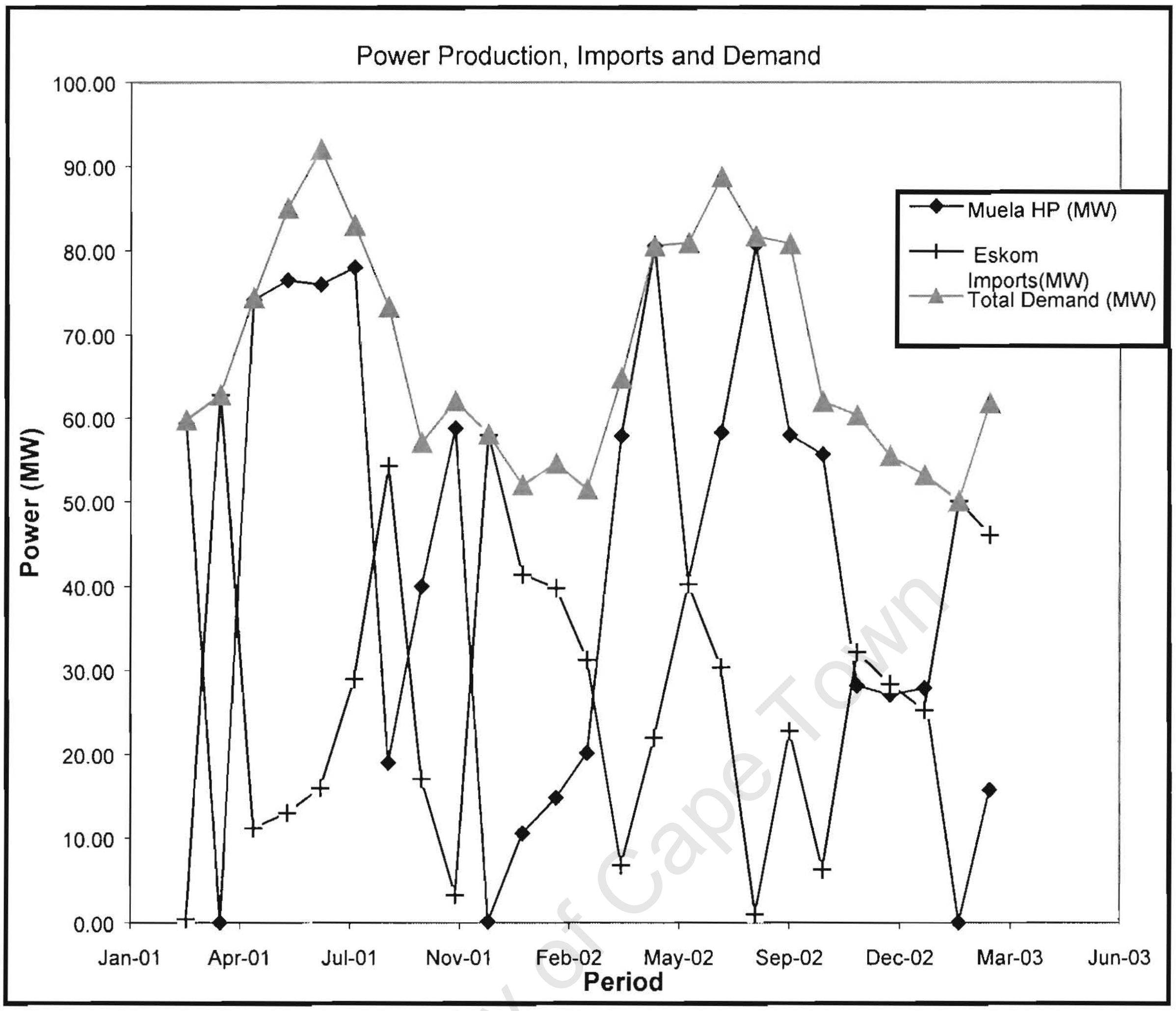
Figure 5.2: Electrical Energy Output at Muela Hydropower station



Sources: Department of Energy, Lesotho Electricity Corporation and LHDA.

Figure 5.2 indicates that the actual energy output from 1998 to 2003 followed the same trend as the designed energy output. The difference occurred in the first three months of Muela operation where the energy produced is higher compared to the designed electrical energy requirement. The highest energy output occurred at the early stage between November 1998 and February 1999. The situation occurred during the commissioning stage when the plant generated more power beyond their nominal capacity, a test to demonstrate that the plant can sustain high peak demands. Each turbine unit generates up to 30 MW during the operations testing period (Hoohlo, 2002). Similarly, the units were undertaking technical acceptance and operational tests discussed earlier. The noticeable trend of lowest point was November 1999, April 2001 and February 2003. The minimum energy output occurred due to the planned maintenance on the plant and in the tunnels. The absorption of physical technology was high as the generated electricity was acceptable and in some cases even higher than the designed energy output.

Figure 5.3: Power Produced against Peak Demand and Power Imports



Sources: Department of Energy, Lesotho Electricity Corporation and LHDA

Figure 5.3 also shows the plant utilisation against monthly peak demand. The figure shows that the power imports from Eskom supplemented the production of Muela plant to meet the total peak demand. The calculated average plant utilisation during peak demand is approximately 60 percent, implying that since the commissioning of the plant the imports from Eskom, South Afrıca was only 40 percent of peak demand. It is also evident that Muela plant on its own is unable to meet the base load for the country except in some extreme situations when there is maintenance within the plant as mentioned earlier.

Table 5.11 outlines an overall national electrical energy demand and peak power demands on monthly for two physıcal years, March 2001 to March 2003. It also shows recent overall performance of Muela Hydropower station during that period.

Table 5.11: Overall National Electricity Supply from March 2001 - March 2003

Month	Muela (MW)	Eskom (MW)	Total Demand (MW)	Muela (GWh)	Eskom (GWh)	Total Energy (GWh)
Mar-01	59.40	0.40	59.80	27.38	2.86	30.23
Apr-01	0.00	62.80	62.80	1.75	24.58	26.33
May-01	74.20	11.20	74.40	36.83	0.56	37.39
Jun-01	76.50	13.00	85.00	38.63	0.42	39.06
Jul-01	76.00	16.00	92.00	41.68	1.08	42.76
Aug-01	78.00	29.00	83.00	41.28	0.37	41.65
Sep-01	19.00	54.30	73.30	38.85	1.52	40.37
Oct-01	40.00	17.10	57.10	29.78	0.45	30.23
Nov-01	58.80	3.30	62.10	29.43	0.25	29.68
Dec-01	0.10	58.00	58.10	21.98	3.94	25.92
Jan-02	10.60	41.40	52.00	25.98	0.90	26.88
Feb-02	14.80	39.80	54.60	25.16	0.60	25.76
Mar-02	20.20	31.30	51.50	26.65	0.64	27.29
Apr-02	57.90	6.80	64.80	29.79	0.51	30.30
May-02	80.55	21.99	80.55	36.03	0.72	36.74
Jun-02	40.65	40.25	80.90	37.06	4.44	41.49
Jul-02	58.30	30.40	88.70	38.87	5.01	43.87
Aug-02	80.70	1.00	81.70	37.55	1.90	39.45
Sep-02	58.00	22.80	80.80	32.86	1.12	33.97
Oct-02	55.70	6.30	62.00	28.90	0.84	29.74
Nov-02	28.20	32.20	60.40	27.50	0.78	28.27
Dec-02	27.10	28.40	55.50	26.57	0.68	27.25
Jan-03	27.90	25.30	53.20	26.59	0.42	27.02
Feb-03	0.00	50.10	50.10	0.00	24.78	24.78
Mar-03	15.76	46.08	61.84	21.03	7.98	29.00
Average	**42.4**	**27.6**	**67.5**	**29.124**	**3.493**	**32.617**

Sources: Department of Energy, Lesotho Electricity Corporation and LHDA

Table 5.11 above also shows that power imports occur for short periods, as the average monthly imports of electricity during the period were approximately 3GWh as compared to average of 30GWh supplied from Muela plant. The trend implies that imports were only 10 percent of the required electrical energy since the commissioning of Muela hydropower plant.

5.9 Operation and Maintenance Activities (Technology Replication)

In 2002, Muela Hydropower station has a complement of about 65 people in three main divisions: 10 in administration and management, 16 in operations and 39 in maintenance. The operators work on a five-shift system with three technicians per shift, with always one shift free while another is working at the reservoir. The free shift is for any emergencies. In addition to normal operations of Muela station, the workers regulate the intake of water from the main reservoir Katse, which connects to Muela hydropower by 45-km water transfer tunnel. The operators also monitor the pumps at Ngoajane site to measure and record the amount of water transfer to South Africa on daily basis. The objectives of the operations and maintenance personnel concerning hydropower are to ensure following:

- Revenue targets in respect of water royalties and electricity sales

- Water transfer commitment within a target of 98 percent reliability
- The obligations to LEC regarding electricity generation
- Effectiveness in maintenance of Muela hydropower plant and equipment to meet reliability targets
- Safety targets towards a dam and surveillance as well as safe working environment
- Control cost below the targeted cost per MW hours generated

The operation and maintenance personnel at Muela hydropower plant use SAP materials management module and planned maintenance module to ensure discipline and quality of the events. The generation model developed to simulate the daily operation of the transfer tunnel, headpond, hydropower plant as well as the tailpond and delivery tunnel. The plant management reviews the above-mentioned objectives on a monthly basis to ensure consistency in reliability, revenue, electricity generated and the water delivered.

The important operation process for water management and electricity generation includes:

- Review of two-day load forecast from LEC and schedule for operations
- Checking status of the plant and monitoring deviations
- Responding to deviations and link maintenance process
- Monitoring the whole plant according to schedule

The maintenance section is responsible for plant modifications and routine maintenance. They also conduct control and protection activities. The other essential processes are immediate response to request, scheduling plan and organising events, executing work, testing and handing over to the production. In general, the maintenance is responsible for the mechanical, electrical, control and protection, civil maintenance, general works including their modifications, planning and documenting control as well as stores and procurement. The approved share of operational costs is 48 percent for electricity generation and 52 percent on transfer water activities.

The Muela hydropower station comprises of a spare parts store within the site and the management is responsible for procurement process. The Finance Section in Maseru is responsible for purchasing and supplies. Management is already building capacity so that the most required spares should always be available in the stock. There is a workshop facility for electrical and mechanical equipment within the hydropower station premises. However, the main concern is reliability and regular supply of spare parts and complementary parts from the manufacturers. The plant management relies on external technical expertise for major repairs and maintenance.

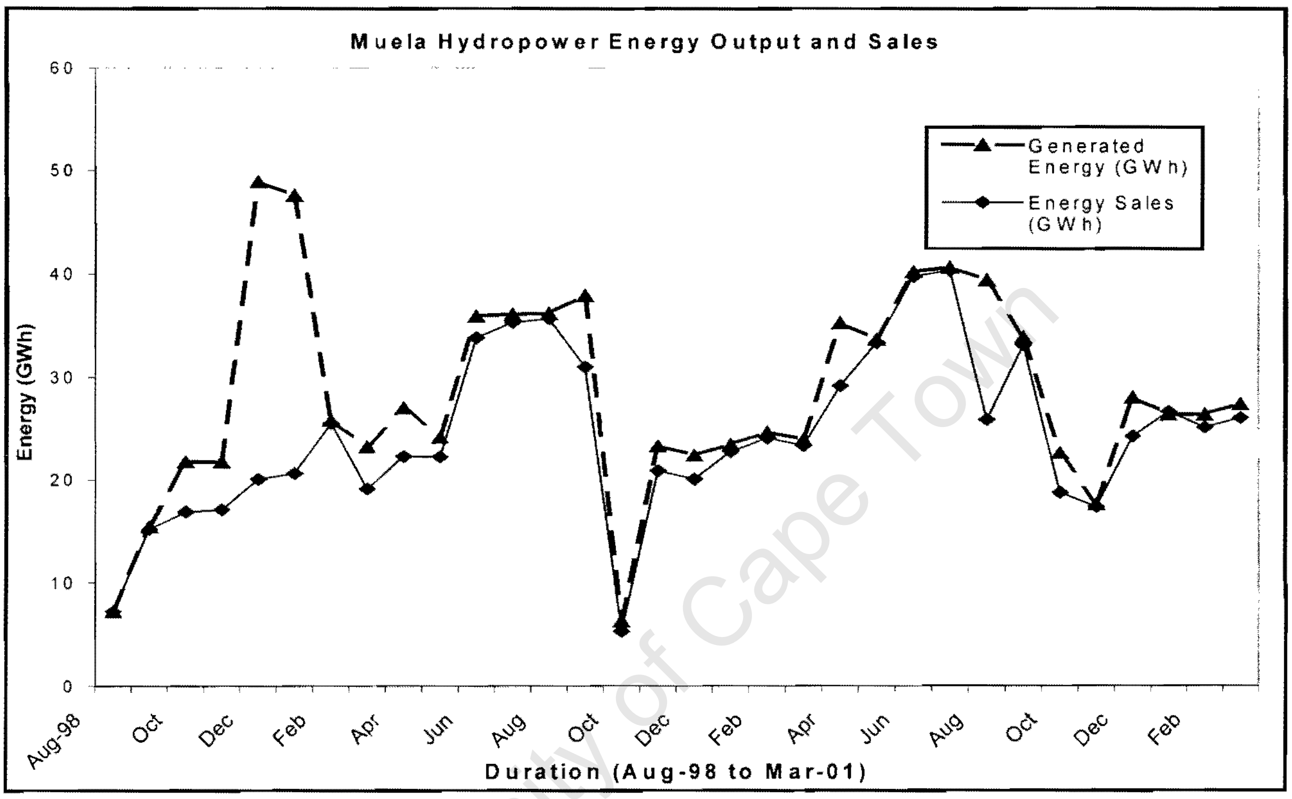
The inhibiting factor that affects the reliability of electricity supply and the operation of the plant is the water delivery component as it supersedes the electricity generation activities because the hydropower is along the water delivery tunnel to South Africa. However, the treaty obliges LHDA to meet the annual water transfer requirements. The operators have flexibility to generate more electricity during peak demand and less during off-peak period. On the other hand, the operators adjust the water flow to bypass the turbines to meet the water delivery obligations stipulated in the treaty. The agreement set an obligation to meet specific monthly schedule with 98 percent reliability. Therefore, electricity generation can follow load demand curve especially when there are no technical problems within the plant.

One of the important factors at Muela hydropower station is the arrangement of a maintenance contract with external contractors for the installation of the power plant. The arrangement will enable the technicians to learn from the maintenance experts even after commissioning. However, the maintenance contact arrangement can disallow the technicians to undertake thorough maintenance and troubleshooting independently, as the assigned contractor is responsible for such activities.

5.10 Commercialisation of the Power Plant

According to the developed integrated framework for technology transfer, the technology becomes commercial after operating according to designed operations levels, adaptable and being replicable. The commercial tests focus on the cash flow and economic performance of operations without subsidies or any form of financial assistance. Figure 5.3 illustrates the trend of revenue from electrical energy sales for the within the first three years of operation of the plant thus from 1998 to 2001. The energy output is similar to the trend discussed in section 5.8.

Figure 5.4: Energy Output and Sales of Electricity

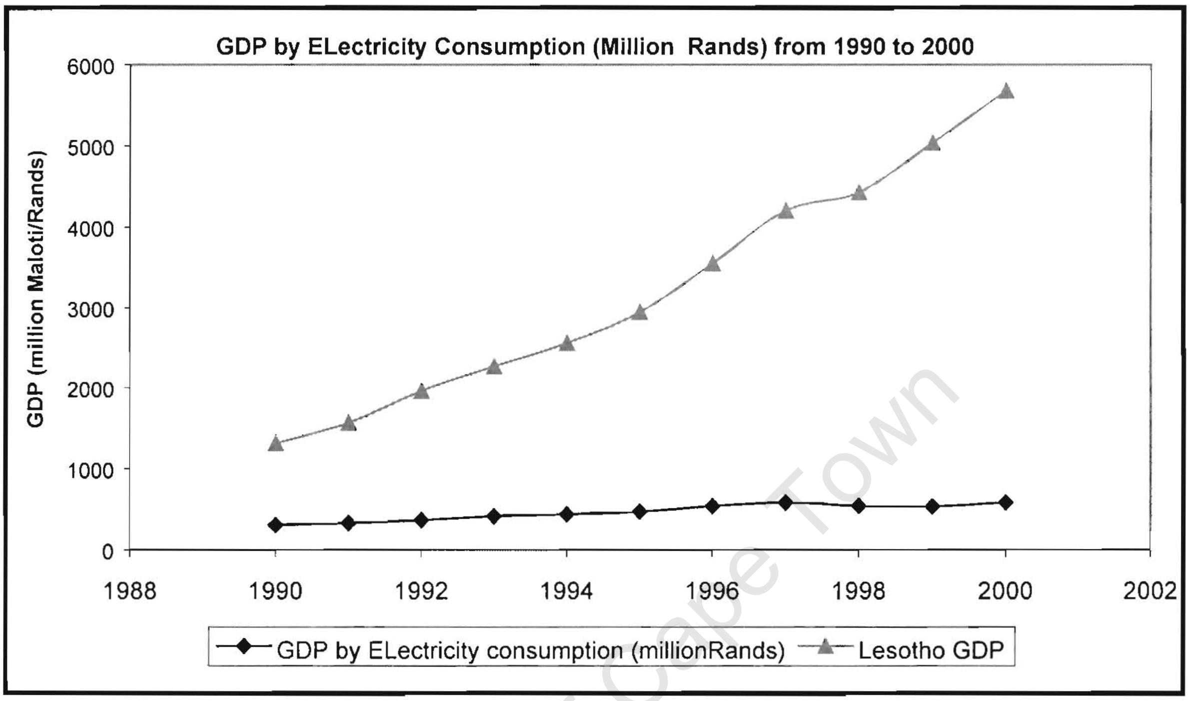


Source: Lesotho Electricity Corporation, 2002

Figure 5.4 above indicates that the energy output from 1998 to 2001 followed the same trend as the energy sales. The difference occurred in the first three months of Muela operation where the generated energy tends to be very high as compared to energy sold. The contractors were testing the maximum amount of power that the plant could generate. Similarly, they might be undertaking technical acceptance and operational tests discussed earlier. During the months of October and November 1999, the generated electricity and sales were low because of civil works in the tunnels.

Furthermore, Figure 5.4 also shows the relationship of generated energy with the seasonal changes where the winter months from May-September show higher generated energy. Conversely, the plant generates minimal energy during the hot summer months from October to January. During low energy-demand months, some units are shutdown in order to optimise and monitor the status of the water transferring tunnels. The current electrical energy demand is high and the revenue will increase with time due to the ongoing electrification programme and expansion of the grid throughout the country and emerging textile industries in Maseru and nearby towns. In addition, it is important to note that the electrical energy demand also has a strong correlation with the overall economic development especially when utilised for productive purposes. The generated electricity has positive effect on the gross domestic product (GDP) in Lesotho as Figure 5.4 shows.

Figure 5.4: The Lesotho GDP by Electricity from 1990 to 2000



Source: Bureau of Statistics Lesotho, 2001

Figure 5.4 also indicates that there was a remarkable increase in GDP but less increase in electricity particularly between 1995 and 1997. The growth became slightly constant in 1998, and increased again in 2000. The slight drop occurred when the energy intensive activities of construction and installations took place within the Muela hydropower station and the Lesotho Highlands Water Project. Apart from the indicated factors, technology acquisition had a positive impact on the GDP of Lesotho.

5.11 Concluding Remarks

The process of transferring energy technology depends on the scale and complexity of the technology. The referenced case of Muela hydropower technology is an outcome of a bi-national government-to-government engineering joint venture. The scale and the nature of the project led to long negotiations and studies before implementation. Similarly, the size of the entire LHWP and component of Muela hydropower technology also indicates the large scope and complexity of determining the areas of technology transfer as the project included several participants and different stages of development. The application of the developed integrated framework for technology transfer has stages corresponding to the activities of the project within a short period while some require long period of observation.

The technology initiation stage shows full participation of Lesotho personnel in every aspect of the project from the planning to final decision-making process and they gained experience as early as during the pre-feasibility studies undertaken. The information also shows the high participation level of the international companies and South African based companies and individual personnel especially where Lesotho people lack the necessary skills and resources.

The chapter also shows that technology selection is one of the challenging steps during the technology initiation stage. The process started with selection of the site for the plant. Secondly, technology selection considered several variables regarding the environmental as well as engineering parameters of the technology and the plant. In addition, technology selection considered the financial and economic factors pertinent to the hydropower technology. The information also shows adequate financial resources, particularly in foreign currency, play a vital role in the success of technology transfer.

Technology internalisation stage includes creation of en enabling environment, identification and application of technology transfer mechanism as well as the technology absorption activities. The data and information illustrate that technology transfer was successful up this stage as the plant was installed and it is operating as planned and designed.

The technology diffusion stage includes capacity for improvement of plant performance, replication and troubleshooting and full commercialisation of the technology. The stage also depends on the external factors like unplanned breakdowns, load forecast and markets demand. The plant generates electricity in accordance with the designed and planned energy output with time although some unplanned shutdowns occur due to lack of troubleshooting skills. The availability of plant and capacity utilisation is reasonable as the Muela power plant meets the base load as well as more than 60 percent of the peak demands of the country. The plant is also under operations and maintenance of the local Lesotho people with assistance of maintenance contractor as and when necessary. The available personnel is still learning and gaining capability on troubleshooting, as the plant is only five years and yet the only one of such size and type in the country. The plant is also generating revenue and it has impact on the overall GDP of the country as illustrated.

There were number of different countries involved in the management of Muela hydropower station during the construction and installation mainly from South Africa and expatriates due to insufficient managerial and relevant technical expertise in the country by then. Therefore, there was technology transfer from the foreign companies and South Africa as it is another partner to the joint venture of Lesotho Highlands Water Project. In addition, LHDA personnel went for training prior and during the installation processes. The purpose of training was to ensure adoption and adaptation of technical knowledge and technological management skills especially for operation and maintenance. The next chapter will discuss the essential findings, gaps and barriers from the fieldwork and acquired information on implementation of hydropower technology. The basis of discussion will follow the stages of integrated framework for technology transfer.

CHAPTER 6

ANALYSIS AND KEY FINDINGS

6.1 Introduction

The analysis of data and information of key findings is important to determine the success of technology transfer and to identify gaps in the project. The objective of the chapter is to analyse the information acquired during the field visit to the Muela hydropower station by applying it to the framework suggested in Chapter 3. This analysis will assist to identify if any deliberate effort was made by the technology suppliers to transfer technologies to the recipients, and to provide information for useful suggestions regarding future technology transactions for Lesotho. The analysis will investigate if the project preparation and implementation followed the steps and stages of the framework as they provide a basis for technology transfer. Finally, the analysis will assist to determine the specific areas of learning and those that requires improvement for future work.

6.2 Methodology

The suggested framework consists of the three main stages. Each stage forms the basis of the analysis. The first stage is energy technology initiation that refers to the identification and assessment of appropriate technology. The analysis is to determine key input from the plan of the national development programme of the country towards technology transfer. The second stage is the internalisation of technology that includes technology imports and absorption of technology imported. The stage also involves creation and promotion of an enabling environment as a prerequisite for successful technology transfer. The enabling environment includes intensive and relevant personnel training to undertake certain activities including management, operations and maintenance of the selected machinery and equipment.

The last stage is diffusion of energy technology. It consists of technology replication and full commercialisation. The stage requires techno-economic skills in addition to normal traditional technical skills. These skills include marketing simulation strategies and investment strategies. The last stage also includes an evaluation of transferred technology on the effectiveness of the transfer process in terms of economic factors, market impact, political acceptance as well as science and technology human capital.

Generally, the information collected indicates that the hydropower plant is an outcome of a joint venture project between the governments of Lesotho and of the Republic of South Africa for the implementation of Lesotho Highlands Water Project (LHWP). The literature states that in a joint venture mechanism, two parties share the costs and risks as well as the benefits. In the case of LHWP, the South African interests were mainly on water supplied while those of Lesotho were on power production, royalties from water sales, job creation, recreation and extension of the road networks.

6.3 Technology Initiation at Muela Hydropower Station

The history of Muela hydropower station indicates that the idea to build the power plant within the first phase of the Lesotho Highlands Water Project (LHWP) started as early as in 1930 as mentioned before. In order to assist the decision-making process both in Lesotho and in South Africa, took part in the pre-feasibility studies. The intention for the Kingdom of Lesotho to be self-sufficient in electrical energy supply encouraged them to take part in the LHWP. The royalties from water sales also stimulated the decisions to implement the bi-national joint venture and associated activities. The donors particularly the World Bank supported the decision as well with the anticipation that it will improve the development of Lesotho (Hoohlo et al., 2002). The government of Lesotho established the Lesotho Highlands Development Authority (LHDA) to oversee the construction and installations. In addition, LHDA has legal responsibility to generate, operate and maintain the proposed hydropower plant.

6.3.1 National Development Programme

Prior and during the construction of first phase of LHWP, more than 95 percent of electricity requirements for Lesotho were imported from Eskom, South Africa. The needs for electricity in Lesotho were growing due to many development aspirations. Hence, there was a need to search for added supply though supply from Eskom is reliable and has the generation capacity enough to supply South Africa and neighbouring countries. The consideration of hydropower technology was also one of the recommendations in the Lesotho Energy Master Plan (LEMP) of 1991. LEMP recommendations emphasise that the government of Lesotho (GoL) should select hydropower projects strategically and implement only those that were viable when compared to electricity imports from South Africa. The load forecasts presumed that the current installed capacity in South Africa and Lesotho will be substantially enough to meet the power demand until then. The high scenario of load forecast in Figure 4.2 illustrated that the country might need 535 GWh while the annual electrical energy consumption in 2002 was 391 GWh (Lesotho Electricity Corporation, 2003). Therefore, the LEMP provide a basis for planning and development of the power and the entire sector in general.

6.3.2 Needs Assessment Prior to Implementation of LHWP

The government of Lesotho assessed the needs before implementing the Muela hydropower station. Needs assessment realised several energy technological requirements and developmental issues which the implementation of the project would assist the country with. The needs were as follows:

- Anticipation that the project would reduce electricity imports and enhances the security of electricity supply.
- Anticipation that the share of the construction activities to GDP would substantially increase during the construction phase of LHWP including Muela hydropower station.
- The project would have a positive impact on the local labour market during the construction and operation stages.
- There was anticipation that the electricity sales within the country would cover the balance of the payments of imported equipment for the construction of other remaining phases of the project.

Needs assessment also noticed the shortage of technical experts capable to undertake engineering designs and blue prints for the project. The lack sufficient scientific and engineering skills created opportunities for foreign companies, consultants and individuals from South Africa to use their technical knowledge as an appointment for the Lesotho people to gain technical and professional competence. Lesotho people who were trainable, both skilled and semiskilled gained from the experts in many ways. Chapter 5 illustrates the participation level of people for Lesotho especially in the construction of dam and underground powerhouse facility as well as installations of turbines and generators switchgear and transformers as well as 132 kV transmission line.

However, the experience in Lesotho indicates that in many instances, these technologies do not get absorbed easily like in the case of the existing mini hydropower stations which do not perform to their maximum capability. The foreign donor agencies designed and managed most technical projects with little or no input from their local Lesotho counterparts. After they left the country, there was insufficient technical support to maintain these technologies. Hence, for the LHWP and Muela hydropower plant, it was necessary to involve the local counterparts to contribute to the modification of the technology by improving its performance and capacity as well as the quality. The local counterparts know the existing conditions better and are more appropriate for adaptation of the technology to such conditions.

6.4 Selection of Energy Technology

The process of selecting technology started with the comparison and consideration of two sites of installation with different characteristics for civil works and anticipated installations of electrical and mechanical equipment as well as the economic factors. LHDA employed technical experts from the consultants for further technology assessment. Sir Alexander Gibbs & Partners from United Kingdom and Sogreah from France formed a joint consultant group, Gibbs-Sogreah Joint Venture (GSJV), which carried out the hydropower designs on behalf of LHDA while the European Development Fund financed the activity. The objective was to maximise the economic return of the hydropower project in Lesotho. The intention of the overall project was to provide the essential data for re-optimisation of the hydropower component through:

- Constant availability of water on a monthly basis
- Maintaining of operating level of the Katse reservoir
- The size and alignment of the transfer tunnel

6.4.1 Selection of Energy Technology on Technical Aspects

There was an analysis of several technical scenarios before the selection of hydropower system. The dams differed in design, concept and scale, as well as in costs. Preliminary design showed that Muela dam would be a concrete gravity arch while Tlhaka would to be an earth core rock-fill dam. Geologically, the sandstone at Muela site appeared to be consistently hard and massive as compared to the basalt rock at Tlhaka. In addition, the scale of works and the flood diversion requirements were significantly moderate.

The information on the two sites for the hydropower plant sites were part of the feasibility studies of the project in 1988. The upstream reservoir has an operating range in the excess of 60 meters and the losses in the tunnel were quite significant because of the 45-km distance from Katse reservoir intake to hydropower station. International power companies such as Kvaener of Sweden supported Muela hydropower by providing the necessary equipment including the Francis turbines together with the installation of other mechanical equipment, heating and ventilation systems.

Moreover, the study envisaged fewer technical problems at Muela site than at Tlhaka site. Geologically, the sandstone at Muela site appeared to be harder and massive as compared to the basalt rock at Tlhaka. In addition, the scale of works and the flood diversion requirements were significantly moderate at Muela. Based on the above, Muela became the selected site for 80 MW total capacity with 90 percent efficiency with lead operation capacity of 72 MW composed of three units of 24 MW each. The study also envisaged that the plant output capacity would be improved during implementation of phases two and three of the LHWP.

6.4.2 The Selection based on Economic Aspects

The choice between the two proposed hydropower stations considered the economic factors and the differences between the water transfer tunnel and delivery tunnel costs during the first and second phases of LHWP. Finally, the analysis of the general costs and bills of quantity indicated that Muela was cheaper as compared to Tlhaka. The data and information presentation in Chapter

5 outlines the different financial and insurance institutions engaged during the construction of Muela hydropower plants. The financial institutions involved included export credit agencies, Concessionary loans and grants from the local, regional and the international financiers as discussed in Table 5.7.

6.5 Analysis of the Activities within the Technology Internalisation Stage

The technology internalisation stage mainly consists of factors that such as enabling environment and the mechanisms for transfer of technology. The stage also includes the technology absorption stage, which determines whether the technology operates according to the design levels or not.

6.5.1 Creation of an Enabling Environment

The availability of funding, insurance, training of personnel, availability of demonstration data as well as availability of technical personnel and institutions constitutes an enabling environment for technology acquisition. The enabling environment should ensure proper handing over and acquisition of technical expertise to operate the technology. The areas are organisational structure and management style that was similar to the counterparts in South Africa in terms of the skills level and remuneration. The management of Lesotho Highlands Water Project comprises of the Lesotho Highlands Development Authority (LHDA) in Lesotho and the Trans-Caledon Tunnel Authority (TCTA) on the South African side. The two authorities report to the Lesotho Highlands Water Commission (LHWC), a bi-national body consisting of three delegates from Lesotho and South Africa respectively. The LHWC also comprise of the Joint Permanent Technical Commission (JPTC), which has authority for monitoring, as well as advisory and approval functions.

6.5.2 Mechanisms for Technology Transfer Involved

The mechanisms for transfer and acquisition of technology include joint ventures, licensing, collaborative research and development, personnel exchanges and others as stated in Chapters 2 and 3 respectively. The activities at LHWP and Muela hydropower plant involve different mechanisms of technology transfer. The first mechanism was a joint venture managed by the LHWC and discussed with the Joint Permanent Technical Commission (JPTC), and other subsidiary bodies from Lesotho and South Africa. Lesotho aimed at absorbing technology and technical expertise on power generation, getting royalties from water sales, job creation, tourism, recreation, and other benefits while South African objective was to address water demand in industrialised Gauteng Province.

The implementation of the project created opportunities for many small-scale turnkey subcontracts, machinery purchasing, technology tours, technical assistance and technical personnel exchanges discussed in Chapter 5. In addition, expertise that is more technical came from the leading contractors from Germany, United Kingdom, Sweden, France and several subcontractors.

6.5.3 Operation Activities at Muela Hydropower Designed Levels

The installation and operational skills play an essential role in technology internalisation. The acquisition of such skills becomes successful when the imported technology operates at the design levels and conforming to prescribed standards and specifications. However, the technicians and the operators of technology in recipient countries must be competent to undertake operational skills on their own. They must also be capable of identifying reasons for low performance and in some cases be able to carry out modifications to the plant to suit the local conditions and the desired output. Technology absorption is another aspect of the technology internalisation, which addresses the acquisition of installation and operational skills even at Muela hydropower technology. The hydropower system is an imported technology to Lesotho, and hence the acquisition of such skills will help to ensure that imported hardware operates at the designed levels, set specifications and performance levels. The adherence to principle of technology absorption will help the recipient to avoid obsolete and rejected technologies.

The hydropower system is an imported technology to Lesotho. Muela hydropower is comparatively a large-scale technology by standards in Lesotho. The inception phase took six months. The first unit started to generate electricity in August 1998 while the third unit started to generate electricity in January 1999. The essential activities of the Operation and Maintenance Group according to Head Engineer of Operations at the plant are to:

- Achieve revenue targets from water sales royalties and electricity sales
- Control costs below the targeted cost per MWh generated
- Meet water transfer commitment within a target of 98 percent reliability
- Meet the electricity generation obligations using two-day forecast from LEC
- Check plant status, deviations and ensure effectiveness in the maintenance of plant equipment to maintain reliability
- Ensure and meet safety of a dam, surveillance and working environment.

On the other hand, the plant operators and technicians use planned maintenance module to ensure discipline and full benefits for essential maintenance of the plant. Management reviews the above-mentioned activities on a monthly basis by using factors such as reliability, revenue, amount of electricity generated and the water delivered.

As a matter of interest, it was also observed that the technicians trained for operations of Muela hydropower plant were part of the team that installed Katse mini hydropower plant in year 2000 with total capacity of 500 kW. This implies the skills acquired from formal training and during the construction and installation of hydropower technology are available and effective. Therefore, the operators applied the competence and experience acquired during the installation of Muela Hydropower. Eventually, the acquired technological experience will be applicable for future installations and expansions of the existing plants. The information primarily verifies effectiveness of transferred and acquired skills for installations during the first phase of LHWP. Katse mini hydropower operates as a back-up system for normal activities within the main dam because has supply from the national grid during normal operations.

6.5.4 Equipment and Machinery Performance

Capacity utilisation is an indicator that is applicable to determine technology internalisation. Capacity utilisation compares the designed installed capacity against the actual utilised capacity or consumed energy output and the actual production. The Figures 5.1 and 5.2 as well as the Table 5.11 in Chapter 5 show that the installed capacity is operating effectively as it is able to meet 90 percent of the electrical energy requirements of the country. Similarly, the electrical energy released from the hydropower plant follows the same trend as the designed energy output. The power plant operations serve the entire base load of the country. In addition, Muela hydropower plant is able to meet above 60 percent of the monthly peak demands of the country when considering the monthly demands against the Muela production and supplies during peak demands. On the other hand, the designed full load efficiency is 90 percent with generator power factor of 0.85 as in Table 5.6 in Chapter 5. Therefore, the absorption rate, capacity utilisation and operational performance are within the planned and designed productivity levels.

6.6 Energy Technology Diffusion

Technology diffusion stage addresses the issues of adaptation of technology to the local environment, technology replication, full commercialisation and evaluation activities of the hydropower technology as mentioned in Chapter 3.

6.6.1 Energy Technology Adaptation and Modification

Technology adaptation is another stage of integrated framework that determines the degree of technology transfer. It determines the efficiency level of the technology. Efficiency determined the actual resource outputs against the installed or designed capacity. It also provides the information on inputs against the cost per unit produced. Technology adaptation also determines whether the operators are able to adapt technology to the local conditions by sustaining performance at the designed levels.

Technology modification includes measure to improve the performance of the installed technology machinery and equipment with objective to increase its capacity and improve the quality of the output. The Operations and Maintenance Group at Muela hydropower station is responsible for modifications of the plant and the overall plant maintenance. They also conduct control and protection activities. Other modification of the plant output and to respond to electricity and water requests, scheduling plan and organising events, executing work and testing. In addition, Operations and Maintenance Group is responsible for the civil maintenance, general works, mechanical, electrical, control and protection, planning and documenting but there is a maintenance contract arrangement for detailed activities in the plant.

The management maintains a spare parts store within the site and manages the procurement process. In addition, there is a workshop facility near the operation and maintenance offices for equipment repairs and modifications within the hydropower premises. The arrangement indicates that the management has built relevant technical expertise on spare parts procurement. The operation and maintenance personnel are responsible for management of the spare store and to optimise availability of required parts. However, the management relies on external technical expertise for major defects on the hydropower technology components.

The Muela hydropower plant is only five years old and still under a maintenance contract as mentioned. The management contract is also important to enhance the operators with technical knowledge. Therefore, the assigned management contractor works with technicians and operators to do detailed maintenance, repairs or replaces the main components as well as troubleshooting. Ultimately the technicians and operators will be able to identify the problems and apply troubleshooting independently. Several resources such as Harvey (1993) provide detailed problem diagnosis and troubleshooting guidelines for hydropower technology faults in turbines, generators, alternators, electronic governor as well as in switchboards. The guidelines signify the common problems, the probable causes and suggestions for troubleshooting, repairs or any measure to rectify such problems.

6.6.2 Full Commercialisation of Energy Technology

The history of Muela hydropower station shows the actual electrical energy and the designed energy output within the first four years from August 1999 to March 2003 followed the same trend as the designed or forecasted electricity demand. Muela is already generating revenue from electricity sales. In the first year of operation, it generated more than 330GWh, from August 1998 to July 1999. The installation and operation of the plant has positive impact on the Gross Domestic Product (GDP) of the country as well. The concern is to expand the services and optimise its operations in order to reach a commercial stage. Literature shows that some power generating technologies including the hydropower projects may have high capital costs incurred but long return period with low operational costs (WEC, 1998). Therefore, there is an expectation that the plant will reach the break-even point and operate economically with profits within ten years after commissioning.

The market of the plant will also increase when LEC and LHDA become full participating members of Southern African Power Pool (SAPP). LHDA will be able to export excess energy to the regional market. It is important to explore the best options to run the plant as a commercial entity and to attain viability of the plant. The main concern is investigation and analysis of all the possible options for electricity markets within the country and the SAPP region.

6.6.3 Effectiveness of the Transfer Mechanisms on Hydropower System

It is important to apply some measures of the integrated framework for technology transfer to evaluate the effectiveness of process for transferring technology. The analysis for effectiveness of the transfer process considers six indicators that need consideration as mentioned in Chapter 3. The indicators include economic development, the opportunity cost, the market impact, political acceptability, the influence on scientific, technical human capital as well as the performance of the transferred and installed technology. Table 6.1 gives an overview of the effectiveness criteria and the related responses over the hydropower technology.

Table 6.1: Effectiveness of Transfer Mechanisms at LHWP hydropower station

Effectiveness Criterion	**Key Question**	**Response**
1. "Out-the-door"	To determine whether technology was really transferred and operating as designed and installed.	Muela hydropower plant is operational and generates power as planned and designed. The hydropower plant is modern and is under effective management. The plant obtained 4-star NOSA grading for its performance and site safety. The plant supply 90 percent of electrical energy and is able to meet more than 60 percent of peak demand
2. Market Impact	To determine whether the transferred technology has an impact on the power sales and profitability.	The power plant is already collecting revenue but since the plant commissioning in 1999, it has not yet reached the break-even point hence the capital and operational costs are still higher than the revenue from the power sales.
3. Economic Development	To determine whether the transfer efforts led to Lesotho economic development.	The GDP is growing since the commissioning of hydropower in 1999. The economy also increased due to created jobs, new businesses and reliable supply of electricity. Energy sales correspond to energy outcome as in Figure 5.4 under Chapter 5
4. Political Rewards	To determine whether the LHDA as technology is politically acceptable.	The project is accepted and the country is self-sufficient in power production and supply. The technology is well recognised by the policy makers in the country and within the region.

5. Opportunity Costs	To determine the impact of installing hydropower technology as compared to other alternatives of utilising water from Lesotho into RSA.	The main opportunity was implementation of hydropower plant strategically by comparing the costs of importing power from Eskom as stated in the LEMP (1988). The optimisation of water transfer is essential as for South Africa. The reliability and security of supply is important to relief and reduce the imports from Eskom. The hydroelectric generation uses mainly renewable energy sources although the size of the plant is small as compared to the green house gas emissions caused by the regional or the global scale production from other sources. In addition, the irrigation system for the agricultural sector would reduce the transfer of water signed under the treaty and annual obligations.
6. Scientific and Technical human capital	To determine whether the technology has increased the technological capacity and use of research.	The engagement of Lesotho into LHWP and hydropower plant has increased the scientific and technological capacity of the country significantly. The project led to training of several technicians, operators, engineers and scientists in different disciplines including environmental, marketing and commercial studies. As indicated under Chapter 5, training is an ongoing process, which will continue to benefit Lesotho people by utilising their skills within and outside the country. Training also involved hands-on learning in many countries and leading institutions in hydropower technology training such as Eskom Pumped Storage facilities as well as Kafue Gorge Hydropower Training Centre in Zambia in addition to their formal training in Ireland.

Source: Bozeman, 2000; Hoohlo et al., 2003

In addition to stated level of effectiveness of transferred hydropower technology, the level of technical expertise is considerably high at Muela hydropower station. The Manitoba Hydro of Canada was responsible for identification and selection of technicians before commissioning of the plant. Similarly, a subsidiary of Eskom called Rotek Industries (Pty) Ltd. also assessed the skills after commissioning of the plant in year 2001 and declared them satisfactory.

6.7 The Barriers from the Case Study based on the Integrated Framework

Energy technologies such as large hydropower systems require high-level technical skills for optimisation of technology performance. However, these skills were not sufficient within the government or private sector during the project life. Therefore, foreign donor agencies designed and managed the project without sufficient input from the local government officials and Lesotho people. LHDA had to rely heavily on the expatriates for their contracting, professional and consultant services. The situation led to involvement of consultants such as Gibb-Lahmeyer from UK and Germany for coordinating all the engineering, procurement and construction (EPC) contracts on behalf of the LHDA.

LHDA personnel became more actively involved towards the commissioning stages because they went for training during the design and construction stages. The operational and maintenance skills are available but they are not yet eligible to undertake the detailed repairs and refurbishment of the plant. The lack of competency is probably because of the age of the plant as in 2003, the complexity of the technology and due to the fact that it still under maintenance contract may limit their involvement. Maintenance contracts have the advantage of continuity but they create monopoly situations that can be disadvantageous if the chosen contractor is unresponsive and complacent towards transfer of technical skills to the assigned local personnel (Harvey, 1993). On other hand, the training undertaken might not have been comprehensive enough, appropriate or specific to the actual hydropower technology installed. Therefore, troubleshooting and technology modification skills are not readily available. The lack of technical expertise shows that the country still needs technological support.

The design aimed for installation of a state-of-the-art hydropower technology, and reliability of the plant is acceptable although, the plant does not operate up to maximum capacity to supply enough electricity during peak demands since commissioning due to problems identified. The main technical problems affecting the operations is the poor performance of the 132/33kV step-down transformers and defects on the turbines linking Muela with the national grid at Maputsoe industrial area substation. These defects of the turbines also led to shutdowns of the units while undertaking the repair programmes. The regular problems within the plant are associated with the corrosion, erosion and cavitations damages within the check plates.

The non-technical problems include the agreement of prioritising water supply over electricity generation in the treaty. Therefore, electricity generation depends on the water requirements by RSA as partner to LHWP. However, the assigned LHDA operators and technicians had to improve and modify technology to suit the local conditions with little or no input from the expatriates and external maintenance contractors.

There were essential activities that were missing prior and during the installation of the plant. Table 6.2 summarises the analysis of the technology with respect to the stages of the conceptual framework for technology transfer. It shows that the necessary skills and the arrangements of technology transfer and acquisition that were not readily available in Lesotho for Muela hydropower technology within the Lesotho Highlands Water Project. The table also has column with recommendations for the required technical knowledge for effective implementation of such activities and arrangements. The last column also suggests the important roles for Lesotho people, South Africans or the involved Expatriates prior and during the installations and operations.

Table: 6.2: Technology Transfer Analysis based on Framework

Technology Stage	**Skills**	**Necessary Activities and Arrangements**	**Personnel Required**	**Responsible Entities Lesotho/ South Africa/ Expatriates****
Technology Initiation	Indigenous skills	**National Planning** • National development program on short and long term commitments • National dialogue and debates on technological needs, • Formulation of programmes for acquisition and implementation • Information dissemination • Enabling and national policy on technology transfer and national position paper on technology transfer • National agenda on technology transfer • Formulation of Integrated Technology programme (ITP)	Competent and Experienced Energy technology policy makers	LHDA, Government of Lesotho, and stakeholders within the country
	Information and Human Capital	**Technology Assessment** • Detailed study on country-specific energy technologies • Investigation of available technological status • Study on energy needs • Study and comparison on available technological options, as well as their barriers towards the adoption and diffusion • Assessment of different technologies and prioritisation from the available • Take a leading role in technology selection. • Encouragement for self-esteem and sense of ownership towards technologies	Competent and Experienced Technical, Legal and Financial advisers.	Pre-feasibility and feasibility studies carried on by Expatriates, Gibb Sogreah Joint Venture and leading contractors from France, United Kingdom, Germany and Sweden

Technology Internalisation	Creation of enabling environment through Capacity Building	**Technology Access** • Immediate implementation of projects • Development of institutional and technological capacity • Attracting foreign investors and ensuring intellectual property rights (IPR) • Improving the role of private sectors on technology transfer • Eliminating monopoly in energy technology suppliers • Access to multilateral funds, grants and commercial funding	Routine training need Design engineers, Specialised Engineers and Scientists, and Technical Managers	Local Polytechnic. Regional training at Zambia, and South Africa-ESKOM. Overseas training at Ireland.
	Installation & Operation	**Technology Absorption** • Encouragement of public and private sector participation by provision of special technology promotion missions and export promotions • Improvement of local technical skills at all levels	Engineering overseers, Technicians, Installers, Operators	The foreign and South African-based Contractors and Subcontractors.
Technology Diffusion	Troubleshooting and RD&D	**RD& D and Technology Replication** Improve performance, capacity and product quality by • Reduction of operational costs, • Improvement on plant efficiency, • Reduction in resource input, and environmental impacts • Troubleshooting by implementing preventive maintenance programmes.	Operation and Maintenance personnel. Involvement of Design engineers	Mainly Basotho together with Maintenance contractors,
	Marketing	**Full commercialisation** Competitive with other power plants in terms of power sales, productivity, quality and reliability and environmental friendliness	Energy Markets simulators, Energy Managers, Energy Economists	Mainly Basotho within LHDA.

* Basotho = People of Lesotho
**Expatriates = everyone from outside Lesotho and South Africa but mainly from abroad

6.8 Concluding Remarks

The Muela hydropower plant is operating as designed and planned. Therefore, the stages of technology initiation and internalisation occurred effectively, hence technology transfer relating to operation is successful to that level. However, technology diffusion activities still rely on support of external expertise, which account for maintenance contract. The physical technology is performing according to the design levels except for few breakdowns that occur occasionally but the plant is relatively new. LHDA personnel including management, engineers, scientists, technicians, and operators gained technical expertise from formal training, through observing and working closely with their counterparts from South Africa and out of Africa. The continuing personnel exchange with South African Eskom is also helpful and positive indicator for Lesotho to be self-sufficient in power supply and technical expertise.

The important issues identified from the case study include the following:

- Adequate training and technical skills are essential to undertake highly technical projects such as hydropower systems.
- Lack of experienced management to plan and implement highly technical projects can be a setback to any stage of technology transfer.
- Countries like Lesotho are still at the underdeveloped stage and therefore need technical support from experienced countries, especially for complicated power producing technologies.
- The lack of readily available skills to operate technology efficiently can result in prolong technology absorption and lack of technology replication as well as the commercialisation of technology outputs.
- Supplies of energy technologies with little or no backup of technical support after installations often result in failure and redundancy of such technologies.

Strategic transfer of energy technology will assist to eliminate the importation of inappropriate energy technologies into Lesotho. In addition to the above mentioned issues facing the country, the challenges that need consideration include training, scientific and technical human capital, research and development finance, and well-structured private and public institutions.

CHAPTER 7

RECOMMENDATIONS AND CONCLUSIONS

7.0 POLICY RECOMMENDATIONS AND CONCLUSIONS

The chapter discusses two sub topics as both policy recommendations and conclusions separately. Firstly, the discussions will be on the policy recommendations that will try to address some of the barriers identified from the study. Secondly, the discussions will be on conclusions of the study and the proposal for future work on technology transfer implementation and research.

7.1 POLICY RECOMMENDATIONS

It is important to note that developing policy on transfer of energy technologies such as hydropower systems requires the setting of clear objectives that emphasise the actual needs and requirements of technology recipient. Also the recipient countries must be able to select the technologies that they can maintain and replicate with time than complex technologies that requires very high technological skills. The objectives of policy recommendations is mainly to address the following:

- Encourage sustainable scientific and technological development in the recipient country.
- Maximise learning for large-scale energy technology.
- Ensure appropriate selection of maintainable and replicable technologies.
- Ensure technology transfer through initiation, internalisation and diffusion stages.
- Improve accessibility, availability and affordability of energy technologies.

7.1.1 Policy on Technology Transfer Plan

It is important to establish technology transfer plan or guidelines, as this will assist to form an internal perspective before discussing with the technology suppliers. This plan must have an organisational structure for all the technical government departments and utilities, technical educational institutions and financial sectors. The technology transfer plan should address following issues:

- Detailed needs assessment of the country through technology studies and prioritisation of the technologies that uses indigenous energy resources.
- Time bound technology transfer plans and strategies to eliminate all barriers for markets, trading and importation, and intellectual property rights (IPR).
- Strategies for creation of an enabling environment for acquisition of energy technology through capacity building and other means.

The plan will assist the country to have robust position on technology acquisition and to identify the needs independently without the undue influence of the technology suppliers.

7.1.2 Policy on Technology Transfer Mechanism

Successful technology transfer requires involvement of the recipient during initiation stage of technology transfer. The power generating entity such as LHDA in Lesotho should collaborate with the experienced operators both within the region and out of the region. It must also play a leading role to incorporate local expertise and stakeholders for technology selection. The responsible entity must incorporate partners and investors with sound technical expertise and knowledge, experiences and willing to share the economic uncertainties with minimum restrictions. The technological partnership with foreign ownership from the leading entities will assist to acquire technology at meaningful costs. The joint ventures are preferable than foreign direct investment (FDI) because the cost of transferring technology varies indirectly with the degree of foreign ownership. Equity control and ownership of technological assets play essential role in technology transfer because suppliers and recipients become partners and share the risks respectively.

7.1.3 Policy on Research, Development and Demonstration Institution

Energy technologies comprise several engineering disciplines such as mechanical, pneumatic electrical and electronic, mechanic controls as well as special materials. All these areas need improvement mainly through research aimed at alternative productive, efficient and effective designs. Primarily, technology transfer should satisfy the criteria for self-sustaining development in the least developed countries such as Lesotho. It is essential to establish high quality technological institution for research, development and demonstration (RD&D) activities to assist the following:

- Technical standards of industrial and commercial services.
- Equip technicians with necessary skills for improving generation capacity, planning network expansion and refurbishment of technology.
- Develop skills, procedures and software packages through training.
- New techniques which electricity supply industry will easily adapt to.

The RD&D activities will facilitate replication of technology which, is not yet observable in this case studied but it will be practical during the second phase of the LHWP and the planned pumped storage schemes. However, the RD&D activities require funding, which the policy-makers within the energy sector in LDCs such as Lesotho have to consider.

7.1.4 Policy on Human Resource Development

Technology transfer process requires an intensive personnel development through training and the proper allocation of expertise. Training is necessary from the initial planning stage and is part of any project. Training will enable the counterpart personnel from LDCs such as Lesotho to undertake the operational tasks independently after departure of expatriates and consultants. The regional and local academic institutions may provide short and long-term training in addition to normal on-the-job training. Training must include personnel exchanges to other similar plants within and outside the country. Therefore, the governments, together with the assigned expatriates, must take responsibility to ensure that the offered training is appropriate and sufficient. The government must monitor the process and encourage adequate capacity building before departure of expatriates in a project such as the case studied.

In the case of technical and engineering projects such as the case study, the designing and engineering managers of energy technology must always consider the operational and maintenance aspects during the design and planning processes. They must also oversee the installation works to ensure their adherence to the original designs and quality standards specified. Moreover, they must arrange and supervise regular training courses for the operations and maintenance activities. Experienced personnel can assist to train newly recruited staff, as this could be the opportunity to refresh their skills. The technicians and operators have to adhere to their supervision specifications. In most cases, technicians and operators have to carry out their tasks independently. In order to ensure the effective transfer of technical knowledge, the process requires involvement of operation and maintenance staff at the design, construction stages as well as during the technical acceptance and operational tests, quality tests stage and commissioning stages.

7.1.5 Policy on Maintaining Contacts

Some energy technologies such as hydropower systems are site-specific and they involve imported spare parts. Therefore, it is difficult to locate and install the hydropower near the technology manufacturers and equipment suppliers. Delay in the supplies of spare parts and equipment or inaccessibility to the hydropower plant affects the normal operations. It is necessary to maintain good supply chain with the spare parts suppliers, manufacturers as well as the assigned maintenance contractors as part of a maintenance contract. The activity also requires adequate budget to purchase the approved and reliable equipment. Plant management has to identify non-core activities and outsource tasks to local repair workshops, while the complex tasks may require involvement of the respective equipment manufacturers and external expertise. Management also has to interact with the technical specialists and local workshops about the essential repairs and the complimentary parts that are often required in order to achieve reliable operations. On the other hand, the technology suppliers should not focus on market expansions and IPRs of delivered technologies but they have to ensure that such systems are operational and are easy to adapt to the recipient environment. They must also provide necessary technical assistance to allow technology diffusion stage to improve gradually as it seems be most complicated stage of integrated framework for technology transfer. Thus, the process must avoid technology dumping and transfer of near obsolete technologies at all costs.

7.2 CONCLUSIONS

The study outlined some of the important concerns that energy supply entities in the least developed countries (LDCs) and developing countries are experiencing to meet their energy demand. Energy technology transfer, acquisition and operation are important for the LDCs and some developing countries because of insufficient capacity to meet the present and future energy requirements. Coping with this problem is a challenge due to lack of adequate engineering and scientific facilities and skills. The conclusions focus mainly on three issues. Firstly, the theoretical issues of technology transfer in the literature. Secondly, case study with focus on the hydropower technology development and transfer. Lastly, addresses findings from the case study based on the integrated framework for technology transfer.

7.2.1 Technology Transfer Mechanisms

The energy technology and their embedded technical expertise are normally transferred from the highly developed countries to the developing countries and least developed countries, thus the North-South transfer. Moreover, the arrangements normally occur between the private sector within the country or from one country to another. However, the study analysed a technology transfer process that occurred between the Republic of South Africa as a developing country with increasing GNI per capita and Lesotho that is among the least developed countries with low GNI per capita. The study demonstrates the possibility of undertaking technology transfer at the level of governments unlike as it usually occurs between the private firms and entities in the developed countries. The process illustrates that South-South transfer is also conceivable rather than North-South transfer that is very common.

The geographic location of the two countries also shows how neighbouring countries can assist each other to attain technological development irrespective of the goals in transfer mechanism utilised. In the case study of Lesotho Highlands Water Project and Muela hydropower scheme, South Africa covered all the costs for water storage and transfer, as its interests were mainly on water delivery. Conversely, Lesotho covered the costs for power generation facility and gained other benefits including jobs, infrastructure expansion and growth in tourism. Therefore, it is evident that the mechanism where the supplier and recipient sharing the risks is practicable and realistic as in the joint venture mechanism observed and analysed. In addition, several mechanisms of technology transfer such as technical personnel exchanges, subcontractors, blue prints and designs constituted the project at different stages and levels of construction and installations. It is also evident that the LDCs and developing counties may form partnerships at government level to enhance the development needs of their respective countries. The study has illustrated the meaningful way of conducting energy technology transfer from one country to another using the mechanism of joint venture, subcontracting and technical personnel exchanges..

7.2.2 The Performance of the Transferred Energy Technology

The installed hydropower is functioning and operating as planned. The technology provides the essential electrical energy of the country effectively and it has reduced the reliability and risks associated with power imports. The calculated electrical energy availability against total energy demand is approximately 90 percent while the Eskom South Africa supplies the remaining. Muela hydropower plant is also reliable because the installed capacity is able to meet more than 60 percent of the power peak demand per month for the observed period up to March 2003. The plant is able to supply the entire base load for the country based on the operations from March 2001 to March 2003. However, capacity utilisation within the stated mini hydropower systems is comparatively low as they all range below 50 percent of the designed energy output. Therefore, there was improvement although the implementation entities and the size of technologies were different.

7.2.3 The Initiation, Internalisation and Diffusion of the Energy Technology

The study primarily addressed the issue of technology transfer and acquisition with emphasis on the recipient country. The study shows that transfer of energy technology can attain self-sustaining development in the recipient countries provided certain policy are adhered to. The transfer of energy technology becomes effective and successful to benefit both the recipient and the technology supplier when the following issues are satisfied:

- A precise needs assessment of the recipient and proper selection of reliable, efficient and environmentally friendly technologies.
- An availability of enabling environment for technology reception, adoption, adaptation and replication.
- An existence of capacity in the recipient to learn and understand technology development and performance improvement.
- Available local personnel that can be trained as technical managers, engineers, technicians and operators to maintain and utilise technology optimally.

Absorptive capacity of recipient is also very important in technology transfer and can assist to undertake the installations and operations according to the design and specification levels. Replicable energy technology implies that a threshold level of technological capability within the recipients for technology assimilation. Training is vital at any stage of the transfer of energy technology. Eventually, well-maintained and replicated energy technologies will reach commercial status, be accessible and meet the growing electrical energy demand, reduce environmental impacts and assure sustainable development within the recipient especially in the least developed countries.

The case study primarily shows that the technology initiation stage was successful, as the national development programme was clear from the beginning of the project. Needs assessments were also effective, as the electricity demand influenced the installation of hydropower technology as compared to other needs such as irrigation schemes for agricultural sector. The treaty agreements between the two countries also validate that the initiation stage was successful.

Technology internalisation was also successful as far as personnel exchanges, joint venture, subcontracting, equipment and machinery purchasing and embedded technical expertise. Some training was done on operations and maintenance as well as development of hydropower systems, within South Africa, Zambia and in the Republic of Ireland. The accomplished enabling environment also included feasibility studies undertaken. The last component of technology internalisation performed installation and operation of technology according to its design levels as it is supplying the base load for the country and is able to meet the peak demands. Therefore, the activity of technology absorption and assimilation under the integrated framework for technology transfer were effectively successful. The operational performance of the installed power plant contributed positively to the stage of technology internalisation of the integrated framework for technology transfer.

It is also evident from the case study that the purchased physical equipment and technical experts were from other countries apart from the South Africa as partner to the joint venture. The leading companies were from Germany, Sweden, United Kingdom and France. The different demographic backgrounds of technical experts illustrate the large scope of technical knowledge that were absorbed apart from South African-based companies, subcontractors as well as personnel exchanges with Eskom and Trans-Caledon Technical Authority (TCTA). The project implementation had influence from the foreign-based consultants and companies. The case study indicates that there was a deliberate plan to train the technical personnel to undertake the operations immediately after commissioning as they went to Republic of Ireland, Zambia and RSA to learn hydropower development and hands-on experience training.

However, technology diffusion skills and activities such as technology replication, commercialisation, detailed maintenance and troubleshooting were not adequate. The conducted training was relevant but the technicians and assigned engineers could not perform their tasks perfectly because of the uniqueness of the plant with its size and arrangement in the country. The case study shows that although systems operational skills are available but the skills for troubleshooting and product modification of the installed hydropower technology are not sufficient. The unplanned shutdowns and the involvement of the maintenance contract primarily show that Muela hydropower management and technicians rely on external sources to undertake troubleshooting and problem diagnosing activities. In addition, the issue of water transfer obligations stipulated in the treaty makes it difficult for technicians and operators to concentrate on hydropower technology problems and associated troubleshooting measures when necessary. However, with time the operators and technicians will be able to undertake such measures independently. They are currently at the stage of improving their operational and maintenance capability in order to assimilate and replicate the technology by improving its performance, capacity, reliability and quality. Therefore, technology initiation and internalisation stages were successful while skills for technology diffusion stage activities are not adequate and need attention.

The study also illustrates that technology transfer can address the issue of sustainable development and enhance livelihoods of the recipient people living in the least developed countries such as Lesotho. Transfer of energy technologies created jobs starting from the project planning to operational stage while assisting the country to be self-sufficient in power production and electricity supply.

7.3 THE FUTURE WORK

Research on technology transfer is necessary in order to ensure and accelerate sustainable development especially in the energy sector. The following are necessary for future work on technology transfer.

- Needs assessment to identify the specific areas, which the recipient country can offer to the investors in return of technology, embedded technical expertise and acceleration of sustainable development.
- Increasing capability to undertake troubleshooting and problem diagnosing of energy technology as well as learning of efficient operational skills especially for environmentally sound energy technologies.
- Review of completed technological projects with the aim to eliminate problems that might inhibit effective operation of technologies of the same nature in the future.
- Investigation of other mechanisms of technology transfer that can be applicable among the least developed countries in the energy sector and other sectors especially at the government-to-government level.

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LIST OF APPENDICES

APPENDIX A:

GUIDELINE QUESTIONS FOR INFORMATION AND DATA GATHERING REGARDING TECHNOLOGY TRANSFER WITHIN MUELA HYDROPOWER STATION AND MINI HYDROPOWER STATIONS IN LESOTHO

1. **Who initiated the idea and the plan to build hydropower plant?**
    - The focus is on the historical background from the Information Centre of LHDA to determine whether there was technology "Push" or technology "Pull" (demand driven) by Lesotho
    - Was it Lesotho, regional and neighbouring countries including South Africa as a counterpart country of the entire Lesotho Highlands Water Project?
    - Did financiers, donor agencies or the expatriates participate or influence the process?
2. **What was the role of Lesotho and Basotho regarding the national development program if any**?
    - Were there any plans or objectives to develop energy supply technologies including the hydropower systems within the country?
3. **What was the role of Lesotho and Basotho in,**
    - Assessment of the technological needs,
    - Technology Assessment,
    - And Technology selection of Muela hydropower?
4. **How long and at which areas were the consultants involved?**
    - Were they used on short-term contracts?
    - Alternatively, were they taken on management contract as part of decision-makers?
5. **Where were the subcontractors involved during the construction and installation of Muela hydropower from?**
    - Do they originate from Lesotho, South Africa or abroad?
    - Determine whether there was a deliberate effort to transfer skills to Lesotho under constraints of time, costs, and quality and environmental concerns which the contactors had to adhere to?
6. **Considering that hydropower, systems are characterised by high capital costs, medium or long return periods** but very low operation costs as compared to thermal power plants that have high operation costs. Determine whether the government of Lesotho, Department of Energy, Lesotho Electricity Corporation (LEC) and Lesotho Highlands Development Authority (LHDA), had sufficient:
    - Financial and insurance resources to cover the huge capital costs and initial operational costs of the plant
    - Stable macro-environment to attract the investors and partnerships?
7. **Training:**
    - What was the goal of manpower development?
    - Where and at which level were technicians and operators at Muela trained?
    - Were they trained locally, within the SADC region, or abroad?
    - What was the desired level of training?
    - How many were trained?
8. **Plant Operations**
    - Determine the plant utilisation rate? Thus, the actual generation trend against designed and installed capacity?
    - Determine energy output per month as compared to the actual demand and forecasted?

- Has the operations and Muela power generation reduced the electricity imports from Eskom, South Africa? If any, at what level? What about exports to Eskom and the region?
- How is the availability of the plant? At least how many planned and unplanned shutdowns experienced per month/Annum?
- Is the plant able to meet the highest peak demands and what is the trend of monthly demands since 2000/2001?
- Is the plant being able to meet the base load of the country through out the year?

9. Replication:

- How many Engineers and technicians are required to operate the Hydropower power plant?
- How competent is, the capacity and experience built at Muela hydropower.
- Is it competent enough to assemble and install the hydropower technology of the same capacity in the future with limited time and costs?
- Has the induced experience and technical expertise ever tested for installations and operations anywhere within the country and the region?
- Are there any training programmes for management, operations and maintenance personnel?
- Has the technology experience any pre-empted and foreseen problems experienced elsewhere?

10. Commercialisation:

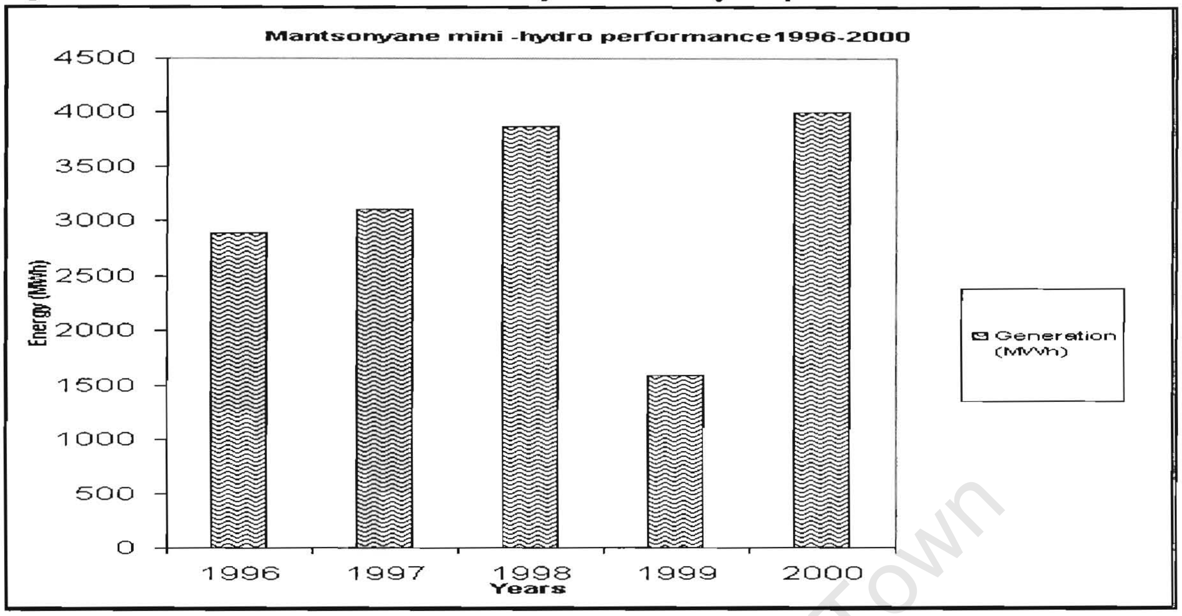
- Are there any plans to commercialise the hydropower?
- Is the plant generating enough revenue to service the capital and operational costs?
- Are there any prospects for capacity expansions and markets penetration to the neighbouring country and the region?
- Are there prospects for the plant to generate as an independent power producer (IPP) with bilateral agreements with customers?

11. The Effectiveness of Transferred technology and mechanisms:

- Are there any, rural enterprises and income generating activities arising from the Muela Hydropower plant?
- Was technology installed addressed all the electrical energy needs and concerns of Lesotho people on reliability, quality of supply and security of supply?
- Is it politically acceptable?
- Has market impact of the electricity and the economy in general improved?
- Has the Science and Technical human capital improved?
- Was the installed hydropower technology essential when compared to other alternatives such as irrigation schemes for Agricultural production? Alternatively, releasing water to South Africa freely and maintain electricity imports from Eskom?

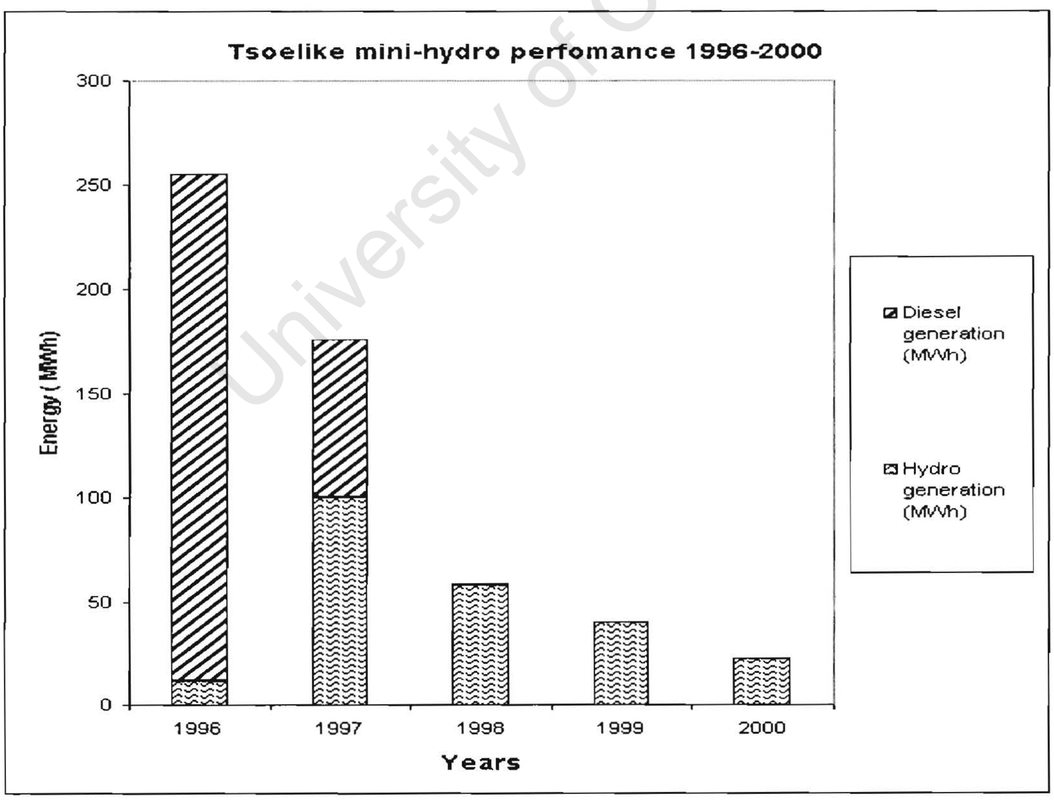
APPENDIX B: Energy Output and Utilisation of Mini Hydropower Stations 1996-2000

Figure B1: Performance of Mantsonyane Mini hydropower station



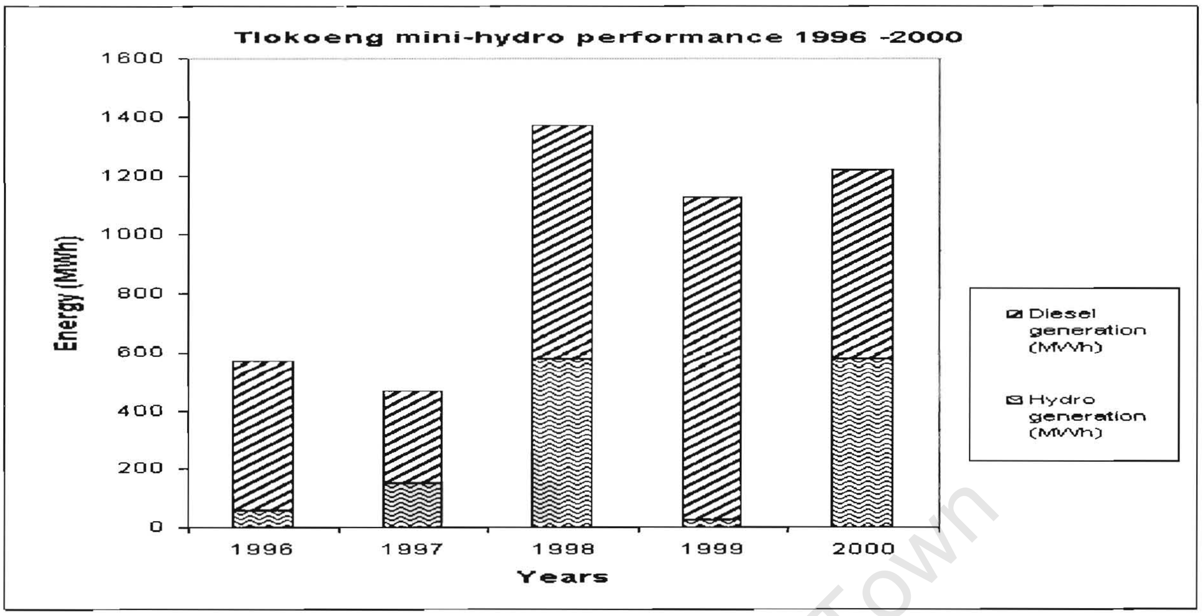
Sources: Department of Energy and Lesotho Electricity Corporation

Figure B2: Performance of Tsoelike Mini hydropower station



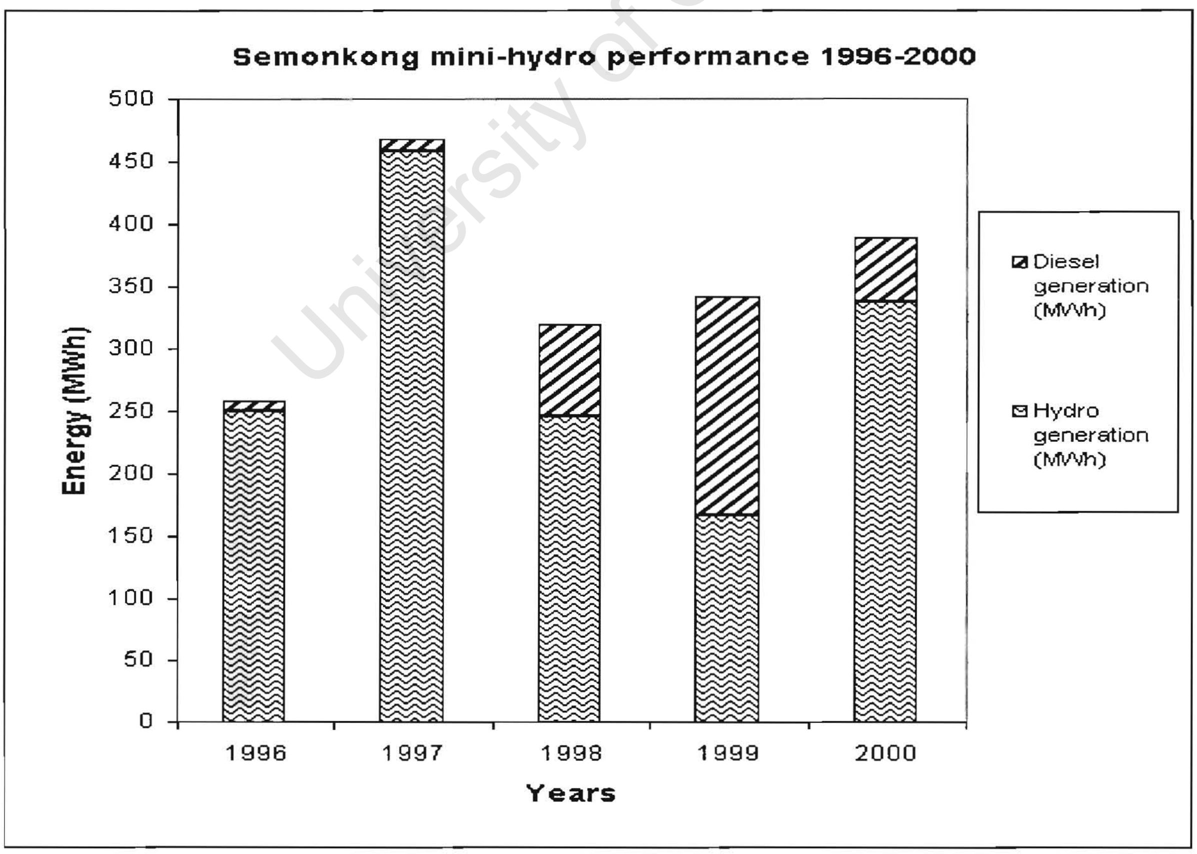
Sources: Department of Energy and Lesotho Electricity Corporation

Figure B3: Performance of Tlokoeng Mini hydropower station



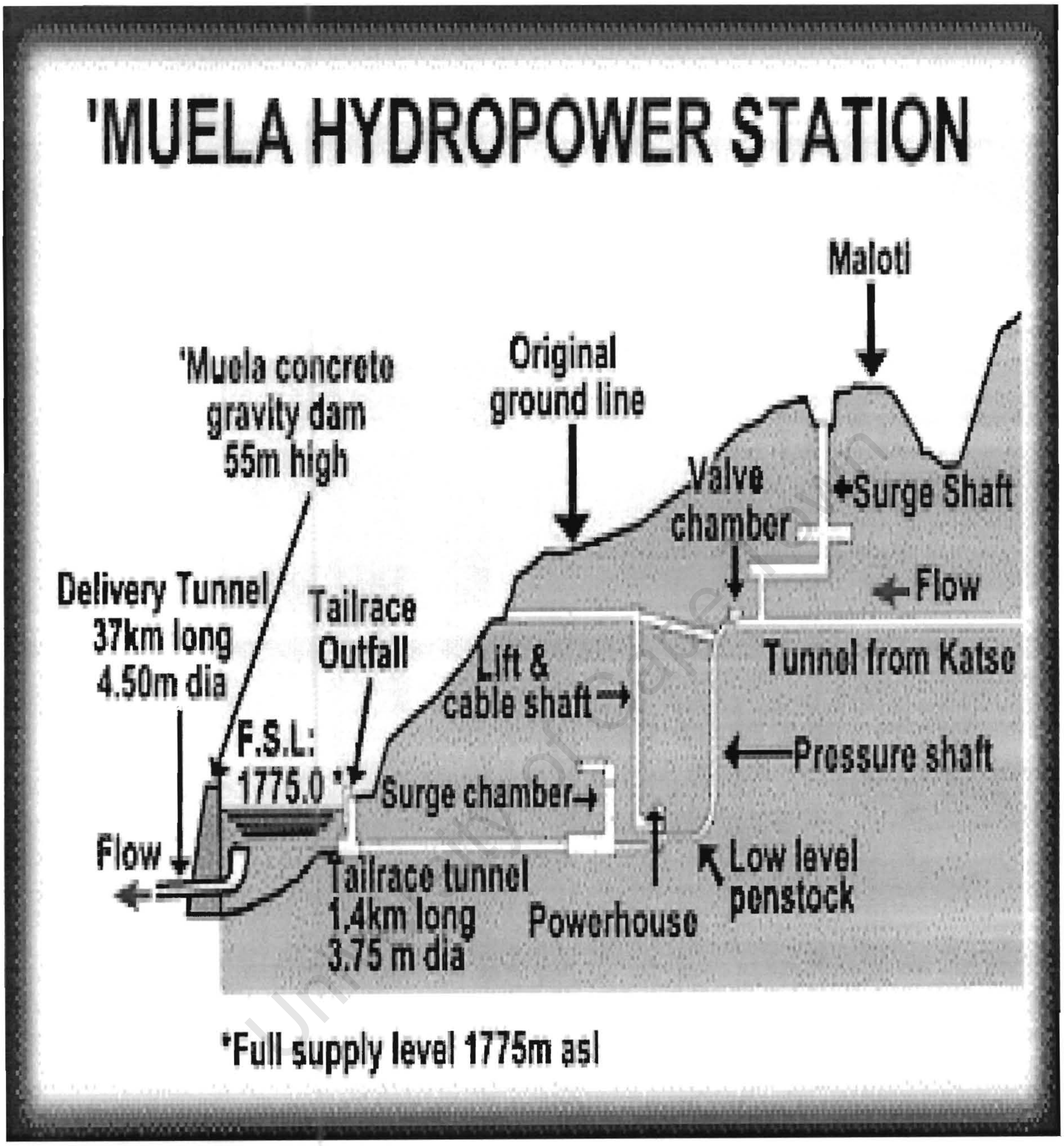
Sources: Department of Energy and Lesotho Electricity Corporation

Figure B4: Performance of Semonkong Mini hydropower station



Sources: Department of Energy and Lesotho Electricity Corporation

APPENDIX C: A Schematic diagram for Muela hydropower Station

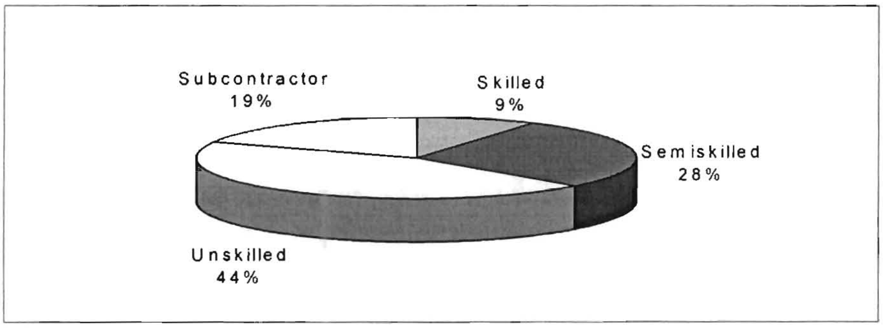


Source: LHDA Information Office, 2003

APPENDIX D: The Activities during Construction and Installation

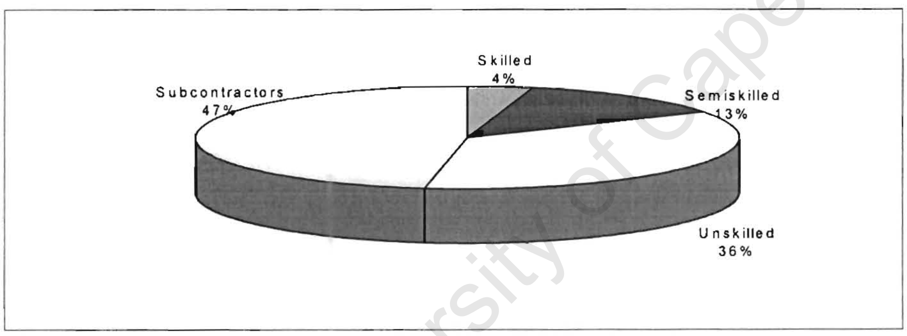
Appendices D1 to D4 illustrate the situation in terms of the level of skills involved. Skilled labours are those with some tertiary education from local technical institutions. The semi-skilled are those that had insufficient technical knowledge but were easily trainable as compared to the unskilled. The Subcontractors involved all the nationals but their background and qualifications were not part of LHDA records.

Figure D1: Labour Competency level for Installations of Underground Powerhouse



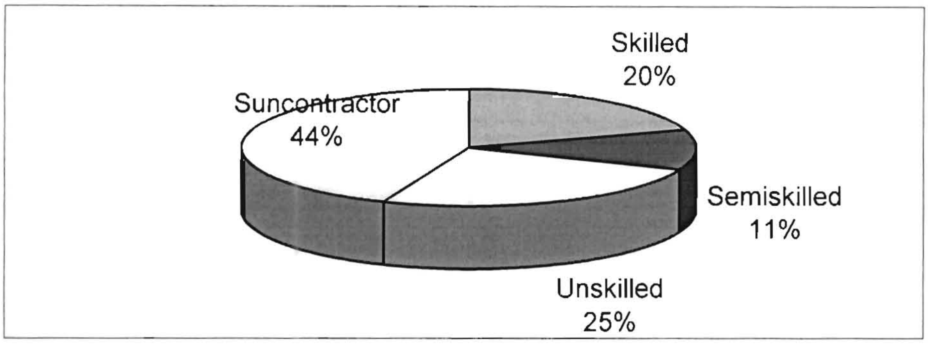
Source: LHDA Monthly Reports 1999

Figure D2: Distribution of Labour for Muela Dam and Appurtenant Works



Source: LHDA Monthly Reports 1999

Figure D3: Personnel capability for Turbines, Generators and Ancillary plant



Source*:* LHDA Monthly Reports 1995-1999

Figure D4: Transformers and 132 kV Switchgear, Transmission line and Substation Bays
Source*:* LHDA Monthly Reports 1995-1999

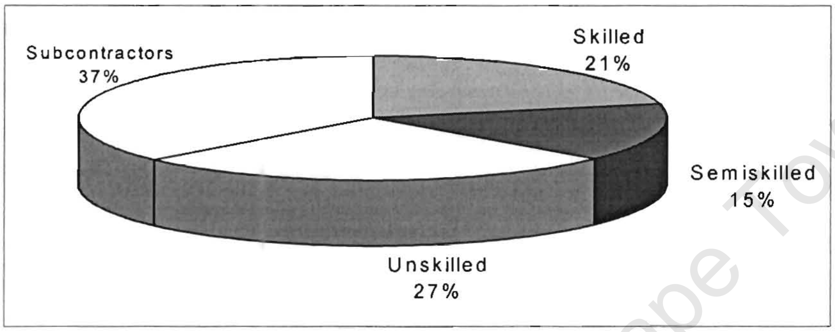


Figure D.4 illustrates the capacity level and the average percentage distribution for the labour involved during the installations of mentioned works. The percentage of skilled labour increased to 21 % while in the previous contracts it remained below 10%. The unskilled labour and the subcontractors also decreased as compared to the previous works. On the other hand, all the Figures D1 to D4 primarily show that the subcontractors dominated the labour part of the personnel engaged during constructions and installations. The situation is rather different from the one in the management level stated under Chapter 5.

APPPENDIX E: Energy Balances for the Muela against the Designed and Forecast

Month	Muela Energy output (GWh)	Designed Energy (GWh)
Sep-98	15.5	28.2
Oct-98	16.9	26.0
Nov-98	21.7	39.2
Dec-98	48.8	37.5
Jan-99	47.5	20.9
Feb-99	25.8	21.4
Mar-99	23.2	23.5
Apr-99	27.0	23.6
May-99	24.1	28.1
Jun-99	35.9	33.4
Jul-99	36.1	33.5
Aug-99	36.2	31.7
Sep-99	37.9	25.1
*Oct-99	6.3	24.1
Nov-99	23.3	23.3
Dec-99	22.4	21.6
Jan-00	23.4	20.8
Feb-00	24.6	21.4
Mar-00	24.6	23.6
Apr-00	23.9	23.6
May-00	35.2	28.1
Jun-00	33.6	33.7
Jul-00	40.2	33.4
Aug-00	40.6	31.8
Sep-00	39.4	25.0
Oct-00	22.6	24.0
Nov-00	17.6	23.4
Dec-00	25.3	21.5
Jan-01	28.0	20.6
Feb-01	26.4	21.2
Mar-01	27.4	24.0
*Apr-01	1.8	23.4
May-01	36.8	27.9
Jun-01	38.6	33.8
Jul-01	41.7	33.0
Aug-01	41.3	31.6
Sep-01	38.9	25.1
Oct-01	29.8	24.0
Nov-01	29.4	23.6
Dec-01	21.9	21.8
Jan-02	25.9	23.9
Feb-02	25.2	24.5
Mar-02	26.6	27.2
Apr-02	29.8	27.0
May-02	36.0	32.0
Jun-02	37.1	38.1
Jul-02	38.9	36.5

Aug-02	37.6	35.8
Sep-02	32.9	29.1
Oct-02	28.9	26.4
Nov-02	27.5	26.6
Dec-02	26.6	24.6
Jan-03	26.6	27.0
*Feb-03	0.0	27.3
Mar-03	21.1	30.3

Source: Lesotho Highlands Development Authority 2003; Gibb Sogreah 1987

*Highlighted rows show the period where minimum energy output because of the maintenance that forced shutdown of one or two turbines.

-The graphical overview of the data in Table Appendix D is in Figures 5.2, 5.3 as well as part of Figure 5.4 under Chapter 5.