MINI- AND MICRO-HYDROPOWER EQUIPMENT MANUFACTURE IN VIETNAM, THAILAND AND THE LAO P.D.R.

John Peter Green

A thesis submitted for the degree of

Doctor of Philosophy



1994



ABSTRACT

The three Mekong Basin riparian countries of Thailand, Vietnam and the Lao People's Democratic Republic (PDR), situated in South-East Asia, are experiencing many economic and political changes which are creating new opportunities for cooperation and development. This thesis argues that there is a large market for mini-hydropower equipment within Vietnam, and a large market for micro-hydropower plant in Thailand, Vietnam and the Lao PDR. It also contests that future developments will best be served by manufacturing much of the powerhouse equipment within the countries concerned, both in terms of the reduced cost of locally made equipment over foreign imports, and in the support which the local manufacturing base will provide in the form of in-country repair and maintenance facilities.

The thesis describes the history and present day situation concerning small-scale hydro development in the three countries, taking into consideration the social, political and economic settings, as well as technological aspects. An assessment is made of the use of mini-hydropower and micro-hydropower equipment in the development of rural electrification, and the prospects for their future use are described in the context of each country's overall rural energy situation.

The study assesses the skills and resources available for the manufacture of mini- and micro-hydropower equipment within the three countries with particular focus upon turbines and governors, though including a review of other electrical and mechanical equipment. Trends in the manufacture of hydropower equipment are highlighted and conclusions are drawn from the research with respect to the suitability of different types of hydropower equipment for manufacture in the region. Recommendations are made concerning future manufacture within each country, and ways in which to promote the local manufacture of equipment.

The study investigates the extent to which the transfer of hydropower technology to, between and within the countries has taken place, and appraises each country's experience with the modes of transfer used. Recommendations are made with respect to the requirements for further technology transfer, and the prospects for regional cooperation. Conclusions are drawn from the study concerning the factors influencing the success of transferring small-scale hydro technology.

It is considered that implementation of the recommendations within this thesis will create an environment conducive to future investment in and development of new schemes within the three countries.

Declaration of originality

I hereby declare that this thesis is original work based on my own research.

John Green

Acknowledgements

I am grateful to my supervisor Dr. Ewen Macpherson for his supporting approach, advice and encouragement. I also would like to acknowledge the critical role of Dr. Robin Wallace who has been thorough and professional throughout, and indeed I would like to thank him for the work he put into enabling me obtain funding and a place at the University. With respect to funding, I am indebted to the United Kingdom Science and Engineering Research Council for their financial support, particularly during the research periods spent in South-East Asia.

I am especially grateful to Prof. Nguyen Duc Loc of the Ministry of Education and Training, in Hanoi, for arranging all of my visits to manufacturers, institutions and hydropower sites throughout my stay in Vietnam. His patience, friendliness and warmth, in conjunction with his wide-ranging knowledge, were instrumental in enabling my visit to be both enjoyable and successful.

Thanks also to Dr. Morakot Tanticharoen, Prof. Prida Wibulswas and the staff of King Mongkut's Institute of Technology, Thonburi, Bangkok, for the use of their facilities and for introducing me to the organisations relevant to my study, and to Pom for her help and friendship. The obvious respect shown to the people of Huay Somsuk and Muangka villages by Lek in Chiang Mai was an inspiration to me, and I thank her for accompanying me to visit the micro-hydropower sites at these villages. The workers at the Chiang Mai micro-hydropower department of the National Energy Administration (now the Department of Energy Affairs) were also very obliging in taking me to several micro-hydropower sites, and putting up with my poor Thai and repetitive questioning. Also within Thailand, essential information, advice and support were willingly provided by Mr. Hayao Adachi of the Mekong Committee, and the United Nations Economic and Social Centre for Asia and the Pacific (ESCAP).

I am indebted to Mr. Lam Ngeunh Phakaysone for arranging provincial visits within the Lao PDR. Without his accompaniment these visits would not have been possible.

A special note of thanks goes to Alison Doig, who I have found pleasant and supportive to work with, and who helped create a friendly working atmosphere in the office.

Thanks also to Jackie Randell for the time she spent introducing me to the many facets of small-scale hydropower, rural electrification, renewable energy and development work. Together with Teresa Anderson she helped me to feel welcome during my first few

months within the department.

I offer my warmest thanks to the many villagers, manufacturer employees, scheme operators, and government employees who welcomed me, answered my questions, and often offered their warmest hospitality. These thanks are also due to the countless others who have offered both support and advice throughout my study.

To my partner, Uvani, who with me endured the months we spent apart whilst I was on field visits ..... words are not enough.

Table of Contents

Abstract i

Declaration of originality ii

Acknowledgements iii

Table of contents v

List of figures xiv

Abbreviations and acronyms xviii

Definitions and notes on currency xx

Chapter 1: INTRODUCTION 1

1.1 BACKGROUND TO THE RESEARCH 1

1.2 RESEARCH RATIONALE 6

1.3 SCOPE OF THE STUDY AND THE THESIS 6

1.4 RESEARCH STRUCTURE 8

1.5 RESEARCH METHODOLOGY 9

1.6 PROBLEMS ENCOUNTERED 11

1.7 THESIS ORGANISATION 12

Chapter 2: HYDROPOWER EQUIPMENT MANUFACTURE AND DESIGNS SUITABLE FOR THE CONDITIONS IN SOUTH-EAST ASIA 14

2.1 INTRODUCTION 14

2.2 TURBINES 19

2.2.1 Crossflow turbines 21

2.2.2 Pelton turbines 25

2.2.3 Turgo turbines 27

2.2.4 Francis turbines 28

2.2.5 Propeller turbines 30

2.2.6 Pumps-as-turbines 30

2.2.7 Other turbines 31

2.3 GENERATORS 31

2.3.1 Synchronous generators 32

2.3.2 Induction generators 33

2.3.3 Other generators 35

2.4 GOVERNORS 35

2.5 INTEGRAL TURBINE AND GENERATOR SETS 38

2.5.1 Family-hydropower 38

2.5.2 Other integral, low capacity units 39

2.5.3 Batteries 41

2.6 OTHER EQUIPMENT 41

2.6.1 Drive mechanisms 41

2.6.2 Bearings 41

2.6.3 Penstocks 43

2.6.4 Flywheels 43

2.6.5 Valves 43

2.6.6 Instrumentation 43

2.7 STANDARDISATION 45

2.8 CHAPTER SUMMARY 45

Chapter 3: TECHNOLOGY TRANSFER AND INTERNATIONAL COOPERATION 47

3.1 INTRODUCTION 47

3.2 TECHNOLOGY TRANSFER 47

3.3 METHODS OF TRANSFERRING TECHNOLOGY 48

3.4 TECHNOLOGY TRANSFER FEES, THE LAW AND RESTRICTIVE PRACTICES IN FORMAL AGREEMENTS 52

3.4.1 Technology transfer fees 52

3.4.2 The law and guidelines affecting technology transfer 53

3.4.3 Restrictive transfer practices 54

3.5 TECHNOLOGY PACKAGING AND DEPENDENCY 54

3.5.1 Packaged technology transfer 54

3.5.2 Unpackaging technology 55

3.5.3 Dependency 55

3.5.4 The effects of aid 55

3.6 THE PARTIES INVOLVED WITH TECHNOLOGY TRANSFER 56

3.6.1 The recipient company and country 56

3.6.2 The supplier company and country 59

3.7 TECHNOLOGY TRANSFER NEEDS WITH RESPECT TO MINI- AND MICRO-HYDROPOWER 62

3.8 FACTORS AFFECTING TECHNOLOGY TRANSFER 64

3.8.1 Nepal: An example of the successful transfer of micro-hydropower technology 66

3.9 INTERNATIONAL AGENCIES AND INTERNATIONAL COOPERATION 67

3.10 CHAPTER SUMMARY 69

Chapter 4: COUNTRY STUDY - VIETNAM 70

4.1 COUNTRY PROFILE 70

4.2 ENERGY SITUATION 71
4.2.1 Energy supply and demand 71
4.2.2 Electricity supply and demand 76

4.3 RURAL ELECTRIFICATION 80
4.3.1 History of rural electrification 80
4.3.2 Government policy towards rural electrification 80
4.3.3 Rural electrification agencies 81
4.3.4 Extent of rural electrification 82

4.4 HYDROPOWER IN VIETNAM 84
4.4.1 Introduction 84
4.4.2 Hydropower institutions 87
4.4.3 Mini- and micro-hydropower 88
4.4.4 Family-hydropower 90
4.4.5 Future plans 92
4.4.6 Requirements for small-scale hydropower development in Vietnam 94

4.5 LOCAL MANUFACTURE OF HYDROPOWER EQUIPMENT 95
4.5.1 Introduction 95
4.5.2 Government policies towards local manufacture of hydropower equipment 96
4.5.3 Acquisition of technological capabilities 96
4.5.4 Turbines 98
4.5.5 Generators 100
4.5.6 Governors 101
4.5.7 Local manufacture of Family-hydropower equipment 101
4.5.8 Other equipment 102
4.5.9 Assessment of companies involved in manufacture of hydropower equipment 103
4.5.10 Test facilities 109

4.5.11 Assessment of the local manufacturing capabilities 110

4.5.12 Requirements for local manufacture 112

4.6 CHAPTER SUMMARY 113

Chapter 5: COUNTRY STUDY - THE LAO PDR 115

5.1 COUNTRY PROFILE 115

5.2 ENERGY SITUATION 116

5.2.1 Energy supply and demand 116

5.2.2 Electricity supply and demand 118

5.3 RURAL ELECTRIFICATION 123

5.3.1 History of rural electrification 123

5.3.2 Government policy towards rural electrification 124

5.3.3 Rural electrification agencies 124

5.3.4 Extent of rural electrification 125

5.4 HYDROPOWER IN THE LAO PDR 126

5.4.1 Introduction 126

5.4.2 Hydropower institutions 127

5.4.3 Micro-hydropower 128

5.4.4 Family-hydropower 132

5.4.5 Future plans 132

5.4.6 Requirements for micro-hydropower development 133

5.5 LOCAL MANUFACTURE OF HYDROPOWER EQUIPMENT 134

5.5.1 Introduction 134

5.5.2 Government policies towards local manufacture of hydropower equipment 134

5.5.3 Acquisition of technological capabilities 135

5.5.4 Turbines 136
5.5.5 Generators 137
5.5.6 Governors 137
5.5.7 Family-hydropower equipment 138
5.5.8 Other equipment 138
5.5.9 Assessment of companies involved in manufacture of hydropower equipment 138
5.5.10 Test facilities 141
5.5.11 Assessment of the local manufacturing capabilities 142
5.5.12 Requirements for local manufacture 142

5.6 CHAPTER SUMMARY 143

Chapter 6: COUNTRY STUDY - THAILAND 145

6.1 COUNTRY PROFILE 145

6.2 ENERGY SITUATION 146
6.2.1 Energy supply and demand 146
6.2.2 Electricity supply and demand 149

6.3 RURAL ELECTRIFICATION 152
6.3.1 History of rural electrification 152
6.3.2 Government policy towards rural electrification 153
6.3.3 Rural electrification agencies 153
6.3.4 Extent of rural electrification 154

6.4 HYDROPOWER IN THAILAND 158
6.4.1 Introduction 158
6.4.2 Hydropower institutions 158
6.4.3 Micro-hydropower 158
6.4.4 Mini-hydropower 162

6.4.5 Future plans 164

6.4.6 Requirements for micro-hydropower and mini-hydropower development 166

6.5 LOCAL MANUFACTURE OF HYDROPOWER EQUIPMENT 166

6.5.1 Introduction 166

6.5.2 Government policies towards local manufacture of hydropower equipment 166

6.5.3 Acquisition of technological capabilities 167

6.5.4 Turbines 169

6.5.5 Generators 172

6.5.6 Governors 172

6.5.7 Family-hydropower equipment 173

6.5.8 Other equipment 173

6.5.9 Assessment of companies involved in manufacture of hydropower equipment 174

6.5.10 Test facilities 177

6.5.11 Assessment of the local manufacturing capabilities 178

6.5.12 Requirements for local manufacture 179

6.6 CHAPTER SUMMARY 179

Chapter 7: ASSESSMENT AND RECOMMENDATIONS 180

7.1 COMPARISON OF EXPERIENCES BETWEEN THE THREE COUNTRIES 180

7.1.1 Introduction 180

7.1.2 Experience with local manufacture 181

7.1.3 Experience with transferring technology 182

7.1.4 Experience with mini- and micro-hydropower development 183

7.2 STRATEGIES FOR THE FUTURE: VIETNAM 184

7.2.1 Markets and demand 184

7.2.2 Hydropower development 185

7.2.3 Local manufacture and technology transfer requirements 187

7.2.4 Additional recommendations to electricity utilities and the Vietnamese government 188

7.3 STRATEGIES FOR THE FUTURE: LAO PDR 190

7.3.1 Markets and demand 190

7.3.2 Hydropower development 191

7.3.3 Local manufacture and technology transfer requirements 193

7.3.4 Additional recommendations to electricity utilities and the Lao government 195

7.3.5 Recommendations to funding agencies and NGOs 196

7.4 STRATEGIES FOR THE FUTURE: THAILAND 196

7.4.1 Markets and demand 196

7.4.2 Hydropower development 197

7.4.3 Local manufacture and technology transfer requirements 198

7.4.4 Additional recommendations to electricity utilities and the Thai government 200

7.5. STRATEGIES FOR THE FUTURE: THE SOUTH-EAST ASIA REGION 200

7.5.1 Regional cooperation 200

7.5.2 Recommendations to funding agencies 204

7.6 OTHER RECOMMENDATIONS 204

7.6.1 Maximum capacity for manufacture of turbines in small workshops 204

7.6.2 Factors contributing to the successful development of local manufacturing capabilities 205

Chapter 8: CONCLUSIONS AND RECOMMENDATIONS FURTHER RESEARCH 207

8.1 CONCLUSIONS 207

8.2 RECOMMENDATIONS FOR FURTHER RESEARCH 213

8.3 POSTSCRIPT 214

BIBLIOGRAPHY 215

APPENDICES 231

Appendix A: List of people with whom discussions were held 231

Appendix B: Technical visits to factories 235

Appendix C: Hydropower schemes visited 236

Appendix D: Country categorisation 237

Appendix E: Organisations offering technology transfer advice and services in South-East Asia 238

Appendix F: Published refereed paper based on the work of this thesis 240

List of Figures

1.1	Map of South-East Asia	3
2.1	Typical costs of micro-hydropower schemes per installed kW, as a function of installed capacity	15
2.2	Cost comparison between two construction methodologies	16
2.3	Share of the total scheme cost by category, as a function of head	16
2.4	Conditions affecting local manufacture of micro-hydropower equipment in industrialised and developing countries	17
2.5	Typical cost of micro-hydropower turbines	19
2.6	Main advantages and disadvantages of the most common materials used in turbine manufacture	20
2.7	Comparison between impulse and reaction turbines	21
2.8	Turbines for mini- and micro-hydropower schemes - applications, advantages and disadvantages	22
2.9	A crossflow turbine	23
2.10	Efficiency curves for some types of turbine	23
2.11	A 475kW Pelton turbine and spare runner	25
2.12	A turgo turbine	27
2.13	A 680kW Chinese Francis turbine installed in Thailand	29
2.14	A 2.2MW Kaplan runner and site schematic	30
2.15	Advantages of using induction generators instead of synchronous generators for isolated schemes	34
2.16	A schematic of an ELC	35
2.17	Advantages and disadvantages of using ELCs rather than flow control governors for micro-hydropower sites	36
2.18	Chinese mechanical-hydraulic governors used in Vietnam	38
2.19	Price of some Family-hydropower equipment from Vietnam and China	39
2.20	Schematic diagram of a 200W Family-hydropower unit	40
2.21	Three 100W Family-hydropower units being used on an irrigation canal in Vietnam	40
2.22	Comparison of drive mechanisms for micro-hydropower equipment	42

2.23	Comparison of the bearings used in hydropower equipment	42
2.24	Comparison of penstock materials	44
3.1	Methods of transferring technology	49
3.2	Repatriation of funds to the supplier of technology	52
3.3	Expectations of the different parties to technology transfer	57
3.4	Impact of technology transfer upon the different actors	58
3.5	Impact of technology transfer upon the supplier	60
4.1	Relief map of Vietnam	72
4.2	The Vietnamese electricity grid network	77
4.3	Generation mix (1991) in Vietnam	78
4.4	Electricity generating costs in Vietnam	78
4.5	Some of the electricity tariffs in Vietnam (1990)	79
4.6	Growth in electricity usage in rural areas of Vietnam	82
4.7	Growth of rural electrified households in Vietnam	83
4.8	Hydropower potential and developments in Vietnam	84
4.9	Map showing the distribution of economically feasible hydropower sites in Vietnam	85
4.10	Small-scale hydropower construction in Vietnam until 1985	86
4.11	Break-even time for 100W Family-hydropower units	92
4.12	Economic feasibility of small-scale hydropower projects	93
4.13	Mini-hydropower projects considered to be economically feasibility in Vietnam	93
4.14	Manufacturing capabilities of Vietnamese factories	98
4.15	A Francis turbine blade at various stages of production: sand cast, ground and polished, and chrome finished	99
4.16	Capabilities of the main manufacturers of hydropower turbines in Vietnam	103
4.17	Cost of equipment from the Hydro Electric Research Centre	105
4.18	A 10kW propeller turbine produced at the Hydro Electric Research Centre	106

4.19	A 200kW Francis runner being finished at the RERC, Hanoi	108
4.20	A turbine runner removed from service in Vietnam due to excessive cavitation	112
5.1	Relief map of the Lao PDR	117
5.2	Total energy consumption by fuel type (1990) in the Lao PDR	118
5.3	Electricity consumption by sector (1990) in the Lao PDR	119
5.4	Electricity production, consumption, import and export in 1990	119
5.5	Provincial map of the Lao PDR showing rural electrification coverage	121
5.6	Electricity prices for local consumption in the Lao PDR, 1990	122
5.7	Installed hydropower schemes in the Lao PDR	129
5.8	A rice mill being driven directly from a micro-hydropower unit at Houay Nam Si, Champassak province	131
5.9	Cost of Family-hydropower units in the northern Lao PDR	132
5.10	The casting mold for the casing of a pump at the Agricultural Tools Making Factory, Vientiane	139
6.1	Relief map of Thailand	147
6.2	Primary commercial energy supply in Thailand (1990)	148
6.3	Rural household energy balance in Thailand (1986)	148
6.4	Installed electrical capacity (1990) of Thailand	150
6.5	Electricity generation by fuel source (1990)	150
6.6	Electricity tariffs for residential and pumping usage in Thailand	152
6.7	Rural electrification target for each Thai National Plan	153
6.8	Level of electrification at each level of local administration (1991)	155
6.9	History and future of village electrification in Thailand	156

6.10	Electricity consumption rates per capita throughout Thailand	157
6.11	A 12kW crossflow turbine manufactured by the ATA, Bangkok, and installed at Muangka village, Chiang Mai province	161
6.12	Mini-hydropower sites completed up to 1990	162
6.13	Output limitations of existing NEA/DEA mini-hydropower schemes	163
6.14	State of mini-hydropower equipment as of July 1990	163
6.15	Equipment costs for ELC governed schemes commissioned between 1983 and 1986	170
6.16	Source of mini-hydropower equipment installed within Thailand	171
6.17	A 40kW crossflow turbine unit produced by the Mining and Industrial Machining Workshop, and installed at Pang Hai, Chiang Mai province	175
7.1	Comparison of the basic conditions in the three countries under study (1990)	180
7.2	Comparison of local manufacturing capabilities of the three countries under study	181
7.3	Division of responsibilities for the installation of a micro-hydropower scheme in Nepal 193	
7.4	Anticipated market for mini- and micro-hydropower equipment in the three countries under study	203
8.1	Manufacturing capabilities of the three countries under study	208
8.2	Recommendations to the three countries under study	211
8.3	Summary of the situation within each of the three countries	212

Abbreviations and Acronyms

Units

A	Amp
Ah	Ampere-hour
GWh	Giga-Watt hours
kg	kilogramme
km	kilometre
kV	kiloVolt
kVA	kiloVolt-Amp
kW	kiloWatt
kWh	kiloWatt-hour
kW/m^2/year	kiloWatt per square metre per year
litres/s	litres per second
l/s	litre per second
m	metre
mm	millimetre
m/s	metre per second
m^3/s	cubic metre per second
MW	MegaWatt
TWh	TeraWatt-hour
V	Volt
W	Watt

Organisations

ADB	Asian Development Bank
ASEAN	Association of South-East Asian Nations
ATA	Alternative Technology Association
DEA	Department of Energy Affairs
EDL	Electricité du Laos
EGAT	Electricity Authority of Thailand
ESCAP	Economic and Social Centre for Asia and the Pacific
GTZ-GATE	Deutsche Gesellschaft für Technische Zusammenarbeit - German Appropriate Technology Exchange
IMF	International Monetary Fund

KMITT	King Mongkut's Institute of Technology Thonburi
MEA	Metropolitan Electricity Authority
NEA	National Energy Administration
NEPO	National Energy Policy Office
PEA	Provincial Electricity Authority
RERC	Renewable Energy Research Centre
SKAT	Swiss Centre for Development in Technology and Management
UNCTAD	United Nations Conference on Trade and Development
UNCTC	United Nations Centre on Transnational Corporations
UNDP	United Nations Development Programme
USAID	United States of America Overseas Aid Organisation

Other abbreviations

a.c.	alternating current
AVR	Automatic Voltage Regulator
boe/day	barrels of oil equivalent per day
BOOT	Build-Own-Operate-Transfer
BOT	Build-Operate-Transfer
d.c.	direct current
ELC	Electronic Load Controller
FINESSE	Financing of Energy Services for Small-Scale Energy-users
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
GSP	Generalised System of Preferences
IGC	Induction Generator Controller
LPG	Liquified Petroleum Gas
NGO	Non-Government Organisation
NRSE	New and Renewable Sources of Energy
PDR	People's Democratic Republic
rpm	revolutions per minute
SI	Système International (d'Unités)
uPVC	unplasticised PolyVinyl Chloride
US	United States of America
US$	United States of America Dollar
VAT	Value Added Tax

Definitions and notes on currency

Referencing

Due to the nature of the research information has been obtained from many sources, including personal communication with many experts within South-East Asia. Information will be referenced to specific interviews and letters throughout the thesis by use of the abbreviation 'pc'. For example, an interview with Professor Vo Sy Huynh will be referenced as [pc: Vo Sy Huynh], the details of which are placed at the end of the bibliography section.

Hydropower categorisation

In accordance with the categorisation used within Thailand, hydropower schemes are referred to in the following way throughout the thesis:

- Mini-hydropower >200kW & <=2MW
- Micro-hydropower >1kW & <= 200kW
- Family-hydropower <= 1kW
- Small-scale hydropower is used as a general term to cover all of these categories.

NGOs and aid organisations

Throughout the thesis reference is made to several different aid organisations, a brief description of which is provided below:

- Intermediate Technology Development Group (ITDG) - this is a non-profit-making organisation which helps to introduce technologies for rural communities in developing countries. They are particularly concerned with disseminating micro-hydropower expertise. In general they do not fund micro-hydropower scheme development directly.

- Deutsche Gesellschaft für Technische Zusammenarbeit - German Appropriate Technology Exchange (GTZ-GATE) - this is the official implementing organisation for technical cooperation of Germany. Their focus is upon poverty alleviation and rural development, and they have a division which works with micro-hydropower development. They are able to fund their own projects.

- United Nations Development Programme (UNDP) - this organisation provides funding and technical support to developing countries programmes aimed at building-up infrastructure.

- charitable NGOs - organisations which provide funding for development projects. These are particularly prominent within the Lao PDR, where the lack of government funds means that much development is dependent upon support from charitable NGOs.

Notes on currency

The prices quoted in this thesis are from 1992, unless otherwise stated, and therefore exchange rates from 1992 are used. These were:

- US$1 = 10,800 Dong (Vietnam)

- US$1 = 720 Kip (Lao PDR)

- US$1 = 25.0 Baht (Thailand)

Prior to 1987 several exchange rates were being used in the Lao PDR as will become apparent in chapter 5.

Other definitions

1 tonne of oil equivalent = 7.31 barrels of oil equivalent

1 billion = 1,000 million

"Give a man a fish, and feed him for a day.
Teach a man to fish, and feed him for a lifetime."

Attributed to Confucius.

CHAPTER ONE: INTRODUCTION

1.1. BACKGROUND TO THE RESEARCH

The three Mekong Basin riparian countries of Thailand, Vietnam and the Lao People's Democratic Republic (PDR), are situated on mainland South-East Asia. The relief map of the region given in figure 1.1 shows the geographical relationship between the countries. The region is going through many political and economic changes, which are creating new opportunities for increased cooperation and trade. Recently there have been significant improvements in relations between Thailand and Vietnam, and progressively improving relations over the last few years between Thailand and the Lao PDR. It is now likely that Vietnam will receive funding from the World Bank, after a moratorium upon its lending to the country since 1975, and the country is presently pursuing its interest in joining the Association of South-East Asian Nations (ASEAN)†, of which Thailand is a founding member. As well as the amelioration of the political situation, there will be improvements made to the transportation infrastructure which has hampered regional cooperation and trade, with the building of the bridge over the Mekong between Thailand and the Laoatian capital, and proposals for new roads linking Thailand with the Lao PDR and Vietnam, and through the Lao PDR to China [Handley, 1993].

There is an increasing demand for energy in the region's rural areas, as the population grows and as people strive for improved standards of living. The link between increased energy consumption and rural development have been noted by many, and electricity is playing an ever increasing role in supplying some of these needs [Ramani, 1992]. Whereas it is generally accepted that the lack of electricity limits the possibilities for development in a region, its presence is not sufficient for that development to occur, but rather it must be present in combination with other favourable conditions [Jechoutek, 1992].

The electrification of rural areas is seldom financially viable in the short term, however, it has ostensibly many other advantages in terms of user benefits and socio-political objectives. The purported benefits generally associated with electrification of rural areas include:

---

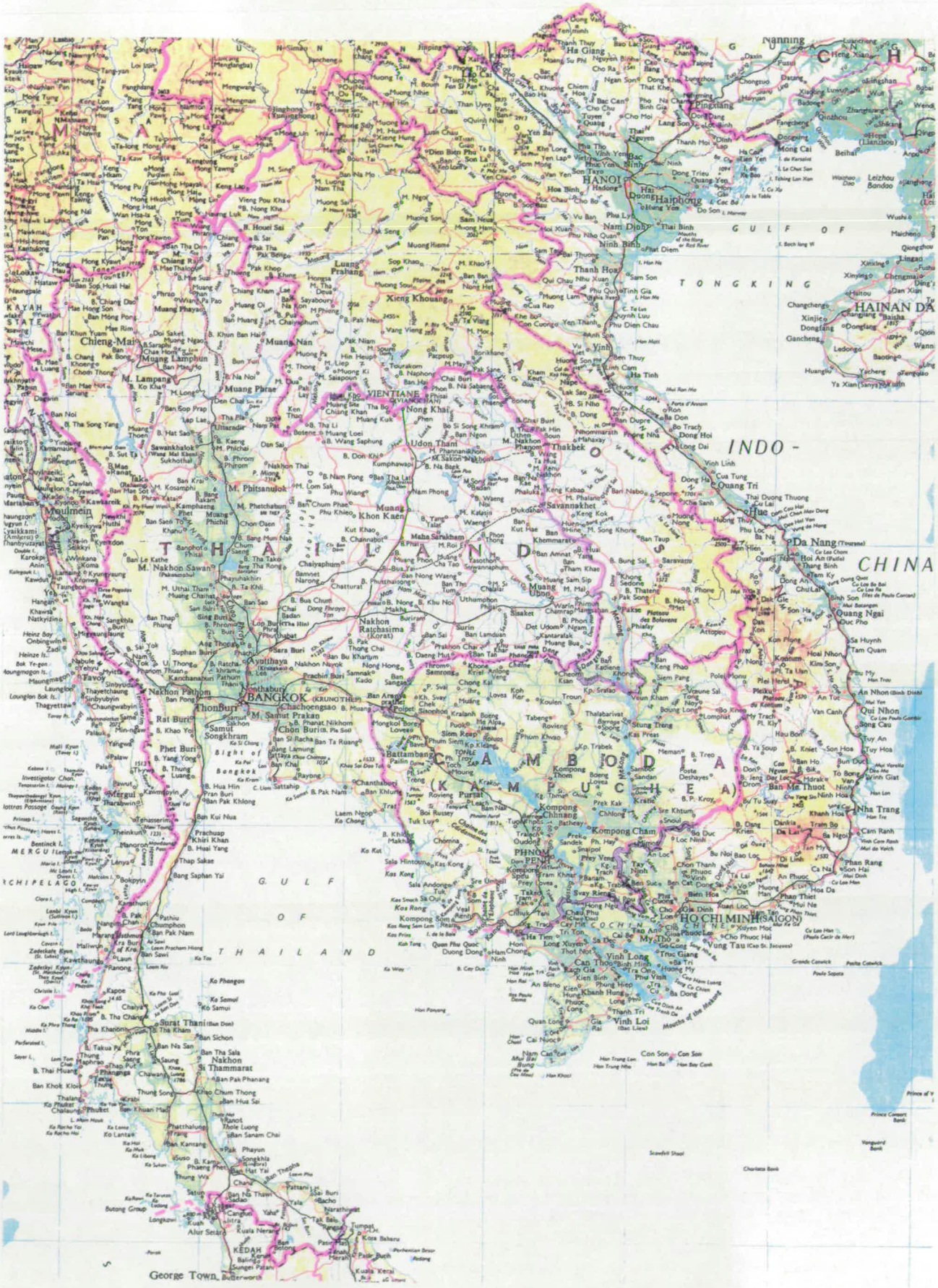
† The members of the ASEAN are presently Brunei, Indonesia, Malaysia, The Philippines, Singapore and Thailand.

- stimulation of the rural economy;
- reduction in deforestation;
- improvement of irrigation facilities;
- improvement of drinking water facilities via water pumping;
- enablement of improved rural health facilities;
- improvement of safety via the provision of lighting;
- reduction of urban migration;
- facilitation of literacy improvements.

Many of these reputed benefits are open to question [Foley, 1989], but electrification of rural areas is still seen both by governments and by the majority of rural people as being of great importance, and governments and international organisations are willing to invest considerable sums of money into its expansion. It is estimated that the World Bank alone loaned approximately US$20 billion for rural electrification during the 1970's [Wallace, 1990].

Electrification of rural areas differs from that of urban areas in many ways, and is generally characterised by the following factors [Randell, 1992; Ramani, 1992]:

- households are widely dispersed;
- electricity consumption rates per household are low;
- load factors are low;
- lighting is the dominant use, leading to consumption being concentrated to the evening time;
- power losses are high where there are long transmission lines;



[Source: Bartholomew]

FIGURE 1.1: Map of South-East Asia

- consumers have difficulty in paying for the supply and appliances.

Electrical grid extension is usually the least-cost-option for a supply to large population centres, however, the more remote an area, the more expensive this option becomes. As well as grid extension, the supply options available for rural electrification include diesel generation, hydropower, solar photovoltaics, biogas, wind power and battery systems†. The cost of each option varies considerably in terms of initial cost, cost of operation, cost of maintenance, and life-time costs. The least-cost-option will also be dependent upon many site specific factors, including demand, likely future increases in demand, local terrain, difficulty of access to the area, the required quality of the supply, and the expected load curve.

Mini- and micro-hydropower schemes have been used as part of many countries' rural electrification programmes. Micro-hydropower schemes are generally used in remote areas where a small amount of power is needed, whereas mini-hydropower schemes are used either in a similar situation, or to provide electricity to a small town, or to stabilise a long grid extension. In some cases micro-hydropower schemes are connected directly to mechanical machines, without electricity being produced, for example to power rice mills. Using mini- and micro-hydropower as the power source for rural electrification has many advantages, including:

- there is no fuel requirement;
- they have long life expectancy of the plant;
- it is a mature, known technology;
- users are not affected by world oil price fluctuations.

The main disadvantages associated with their use include:

- the high initial investment costs;

---

† Technical details and cost comparisons have been thoroughly described by many authors, and will not be covered within this thesis. The reader is referred to the bibliography for further information [Twidell, 1986; Foley, 1989].

- the requirement for skilled operators;
- the supply may be dependent upon seasonal weather variations;
- there is difficulty in increasing the system capacity if demand rises rapidly.

Many of the households in the South-East Asia region remain without a source of electricity, shown for example by the situation in the Lao PDR where only approximately 10% of the 4 million population have access to electricity [Sumphorn Manodham, 1992], leaving it with one of the lowest electricity consumption rates in the world. The areas without a supply characteristically have low population densities, low average household incomes, and are remote from electricity grids, with access to them being difficult.

The huge hydropower resources present within the region provide the countries with great potential for power generation, using both large grid connected schemes and isolated smaller schemes. Many large schemes have been built, however, now, particularly in Thailand, there is a popular movement to prevent the construction of more schemes. In contrast to large hydropower schemes, the effects of mini- and micro-hydropower are generally considered to be environmentally benign.

In 1991 the worldwide capacity of mini- and micro-hydropower schemes under construction was over 400MW, and there was more than a further 4,000MW being planned [WPDC, 1991 (a)]. Although the market is large, it is supplied by an already established, mature industry of over 200 manufacturers worldwide [Wallace, 1990]. There are, however, numerous advantages of manufacturing hydropower equipment in the country where it is to be used, ranging from the reduction in foreign exchange requirements, to the increased body of knowledge and expertise which becomes locally available, and workshops have begun to produce equipment in many developing countries. Designs and fabrication techniques can be adapted to local conditions, and the skills which develop remain available for the maintenance and repair of equipment. Import costs and duty are eliminated, as is the cost of paying for foreign expertise. Although the technological capabilities required in order to produce hydropower equipment have in some situations developed endogenously, there is a requirement in most developing countries for improvements in their design and manufacturing capabilities.

1.2. RESEARCH RATIONALE

Each of the governments of the three countries in this study has expressed its commitment to increasing the provision of electricity to their rural areas. Due to the nature of the areas presently without electricity in the region, both mini- and micro-hydropower schemes are likely to be the least-cost-option for a supply in many cases. There is thus a market for mini- and micro-hydropower power equipment within the region, and with the improvement in relations between the three countries there are increased prospects for trade and cooperation.

An assessment of the skills and capabilities available in each country reveals ways in which the existing facilities for the manufacture of mini- and micro-hydropower equipment may be strengthened. Also, an evaluation of the future plans and potential for mini- and micro-hydropower installations enables effective decisions to be made by individual manufacturers and policy makers. These in turn promote the use of mini- and micro-hydropower schemes, and the manufacture of equipment for these schemes within the region. Also an assessment of the ways in which technology has been acquired, the problems faced and how these have been dealt with by those presently manufacturing equipment within the region, will be of use to others wanting to manufacture their own equipment, both within the region and throughout the world.

1.3. SCOPE OF THE STUDY AND THE THESIS

The aims of the study were to:

- evaluate the hydrological resources within Vietnam, Thailand and the Lao PDR, and the future prospects for the use of mini- and micro-hydropower for the electrification of rural areas within the three countries;

- compare the strategies of the three countries with regards to promoting the effective use of small-scale hydropower schemes;

- assess the market for imported and locally manufactured equipment;

- assess the skills and resources available for the manufacture of small-scale hydropower equipment within the three countries;

- determine ways in which to promote the local manufacture of equipment within the three countries;

- investigate the extent to which technology transfer is presently taking place between the countries, and the prospects for future regional cooperation;

- identify the factors influencing the successful transfer of small-scale hydropower technology.

The thesis presents an assessment of the resource base for the manufacture of mini- and micro-hydropower equipment in the three countries, and the factors which have an influence upon it. It contends that small-scale hydropower equipment can be successfully manufactured within South-East Asia, and recommendations for effective ways forward are made to the government authorities, factory owners and NGOs in each of the three countries. It is hoped that the information and recommendations will be used by these organisations to plan for the future development of local manufacture of micro-hydropower equipment, and where appropriate, mini-hydropower equipment. Whereas much will also be of relevance to other developing countries in the process of implementing mini- and micro-hydropower schemes, the best way forward, however, is likely to be country specific. Indeed, these recommendations take into account the experience of other countries which have similarly been involved in hydropower equipment production.

The thesis focuses upon the technology transfer and local manufacture of mini- and micro-hydropower equipment in the three Mekong Basin riparian countries of Vietnam, Thailand and the Lao PDR. It describes and contrasts the way in which hydropower equipment manufacturing technology has been obtained by each country, and describes the three countries' approaches to rural electrification and energy policy, in the context of mini and micro-hydropower development. It covers the manufacture of powerhouse equipment extending from the penstock to the tailrace. Particular emphasis is placed upon the manufacture of turbines, and to a slightly lesser extent upon generators and governors, in accordance with the focus placed upon these components by most countries embarking upon hydropower equipment production. Other equipment including drive mechanisms, penstock, and bearings, have also receive consideration, whereas little consideration is given to the manufacture of switchgear, transformers, electrical cables, or transmission line equipment. Whereas these may be of importance for a country's industrial growth and self reliance, they are not specific to the manufacture of hydropower equipment, and their development will in most cases be dependent upon

requirements outside the mini- and micro-hydropower sector. The thesis does not include a thorough investigation of site civil works as such studies have been carried out by others‡.

1.4. RESEARCH STRUCTURE

The first year of research, based in Edinburgh, was spent gaining background knowledge on rural electrification, hydropower equipment, technology transfer, as well as socio-economic aspects relevant to the manufacture and use of mini- and micro-hydropower schemes. Research within the three countries was undertaken during two periods totalling nine months from September 1991 to January 1992, and from September 1992 to December 1992. The first visit was spent solely in Thailand, whereas the second visit was spent mainly in Vietnam and the Lao PDR, with a short period in Thailand.

The first two months were spent in Bangkok, based at the School of Energy and Materials of the King Mongkut's Institute of Technology Thonburi (KMITT). The author was able to visit many of the national organisations concerned with rural electrification and small-scale hydropower developments throughout the country, whilst in Bangkok. This enabled the author to collect information and to organise future field visits. During this time he also attended the Asia Energy '91 Conference in Bangkok, and was invited to Kuala Lumpur, in Malaysia, for the FINESSE World Bank Colloquium on the financing of small-scale energy projects in the ASEAN.

Field visits to a variety of hydropower projects in Thailand were made with the National Energy Administration (NEA) and the Appropriate Technology Association (ATA) between November 1991 and January 1992. These were within the provinces of Chiang Mai, Kanchanaburi and Chaiyaphum.

On returning to KMITT in January 1992, the author began to collate the information collected and revisit those organisations in Bangkok with whom he had previously liaised, and which were interested in the research.

Upon returning to the region in September 1992 the author spent the first week in Bangkok in liaison with the Mekong Committee, KMITT and the United Nations. Whilst in Vietnam he was based with the Renewable Energy Research Centre (RERC) of the National Polytechnic University in Hanoi and had access to information at other institutes

---

‡ See Inversin [Inversin, 1986].

and government bodies. Visits were made to all of the organisations known to have made small-scale hydropower equipment within Vietnam. Interviews were arranged with policy makers, district officials, government departments, NGOs and research establishments. Field visits to sites in the South of the country were made accompanied by the Head of the National Programme on New and Renewable Sources of Energy and Head of Hydropower of Electricity Company No. 2. Field visits to the North of the country had to be aborted due to high rainfalls. Visits were also made to Binh Dinh Province and Danang Province, to assess the use of hydropower in these provinces.

A colloquium on the future of hydropower in the Lao PDR, Vietnam and Cambodia was held in Vientiane, Lao PDR, at the end of October 1992. This was a good opportunity to discuss the wider issues relating to hydropower developments in the region. After the colloquium, the author returned to Thailand to meet with intergovernmental organisations and to collate the information collected in Vietnam. At the end of November 1992, the author revisited the Lao PDR and made field visits to micro-hydropower sites, local manufacturers, and provincial officials responsible for micro-hydropower developments in the provinces of Champassak, Saravan and Luang Prabang, and national officials and manufacturers whilst in Vientiane.

1.5. RESEARCH METHODOLOGY

The field visits enabled the researcher to:

- gain access to documents, reports and confidential information only available within the countries;
- liaise with equipment manufacturers and implementing organisations in the three countries;
- meet and hold discussions with engineers, planners and government officials;
- visit mini and micro hydropower sites and demand centres;
- determine the extent and limitations of the technical expertise and manufacturing facilities;
- gain an appreciation of local conditions, including: economy, climate, culture, politics, language and traditions, all of which are very important when putting the

requirement for technology into context for each country.

Visits were made to all of the workshops and factories which manufacture turbines on a regular basis in Thailand and the Lao PDR, and around Hanoi and Ho Chi Minh City in Vietnam. These are the major producers of hydropower equipment in the countries, however, there are several other small rural workshops which have sporadically produced equipment. Appendix A provides the names of the people with whom interviews were held, and Appendix B gives a list of the factories and workshops visited.

Interviews and discussions were also held with all of the countries' main organisations concerned with mini and micro-hydropower development and rural electrification. As shown in appendix A, discussions and interviews were held with electricity utility organisations, government offices at national and district level, NGOs, international organisations, including the United Nations, and academic institutions with departments working in related fields of research. Consideration of the views of manufacturers, implementing organisations, Non Governmental Organisations (NGOs) and district officials was sought, and is taken into account throughout the thesis. Also, copies were taken of relevant publications, and unpublished documents at these organisations and other libraries.

Interviews took the form of guided discussions, with the author having a clear idea of the information which was required, but also being open to the possibility of eliciting other relevant information. This was considered to be better than using rigidly structured questionnaires which would not be flexible enough to cope with the diversity of organisations approached. This technique also reduced the effects of preconceived prejudice, which a rigid questionnaire would have reinforced, and enabled the underlying issues and problems to appear more quickly [Randell, 1992].

Field visits were undertaken to a wide variety of small-scale hydropower schemes in each country, having capacities ranging from several hundred watts to 3.2MW, and where both imported and indigenous equipment had been installed. These sites were chosen to represent a wide cross section of the schemes in terms of capacity, stage of implementation and their effectiveness. Appendix C lists the micro- and mini-hydropower schemes to which field trips were made. Technical information was recorded in a systematic way at each site, whereas information concerning plant reliability and performance was obtained from open discussion with plant operators, owners, national hydropower engineers, and in some cases the electricity consumers. By using guided interviewing of these key people, as well using observation techniques, both quantitative

and qualitative data was obtained. Notes were either taken at the time of interview, or directly afterwards in circumstances where the author had been advised to make the discussion informal. This approach was found to be necessary particularly in Thailand where most plant operators, plant owners and district officials were happy to talk openly in informal conversation, though were more reticent in response to official questionnaires. The field visits enabled the author to see the working conditions in which the equipment was operating, how well they were working, and particular problems which they were facing. Photographs of some of the equipment in use at some of the sites visited and of equipment being manufactured are shown throughout the text.

An interpreter was necessary and available at all times during the field trips and factory visits in both the Lao PDR and Vietnam. Within Thailand this was not always necessary as many officials spoke English, and in other situations a combination of the accompanying Thai nationals' knowledge of English and the author's very basic knowledge of Thai was sufficient.

1.6. PROBLEMS ENCOUNTERED

Several types of difficulties arose due to the particular nature of the study. A short description of them and their effects is presented here.

a) Travel is presently restricted in the Lao PDR, and during visits outside of the capital, Vientiane, it was necessary to be accompanied by a Laoatian national endorsed by the Lao PDR government. There were similar, though less stringent restrictions within Vietnam, whereas the border areas of Thailand were not accessible for political reasons. Travel was also restricted due to the nature of the terrain, roads and weather conditions. These factors meant that certain sites could not be visited and the time spent upon travel to and from the sites was considerable, and often involved considerable expense. This placed a restriction upon the number of schemes which could be visited.

b) There were many discrepancies between different sources of data, and between planned and actually implemented schemes. Cross referencing and analysis of the data, along with visits to sites, factories and other organisations, enabled a fuller picture of the real situation to be made.

c) Lack of data concerning the operating performance of equipment was also evident in each of the countries. Also, in some cases certain data was withheld from the author

for political and/or financial reasons. In most cases the reasons were clear, and these have been taken into account within the thesis.

1.7. THESIS ORGANISATION

There are possibilities for reducing the cost of mini- and micro-hydropower equipment, by using cheaper construction methods, cheaper materials and less complicated designs. Compromises can be made in many cases between efficiency and cost, and there are more benefits to be gained by manufacturing the equipment close to where it is to be used. These benefits and the use of cost reduction techniques are presented in chapter 2. Although the economy of scale associated with small companies is poor, this is compensated by the lower distribution costs and the availability of maintenance facilities. The chapter goes on to describe the various types of mechanical and electrical equipment required for a mini-, or micro-hydropower scheme, focusing upon the suitability for their manufacture in South-East Asia and other developing countries. There are many types of equipment, each requiring different levels of skill, different manufacturing methods and a variety of materials. The suitability of their manufacture will vary from country to country and is also dependent upon an organisation's resources. The chapter focuses upon the manufacture of turbines, generators and governors, briefly comparing the merits of the various materials which can be used for penstock construction, the types of drive mechanisms used to couple the turbine to the generator, and bearing types.

Technology transfer can take many forms, and more than just a knowledge of the technology involved is required. Chapter 3 describes the various factors which must be taken into account in order for the transfer to be a success. Experience is drawn from a variety of situations with parallels to those found in the three countries under focus.

Country studies for Vietnam, the Lao PDR and Thailand are presented in chapters 4, 5 and 6 respectively. A review of each country's energy situation and policies, along with a description of the current level of rural electrification are presented in order to gain a proper perspective of the role which mini- and micro-hydropower can take in the region. The experiences of both government agencies and NGOs involved in mini- and micro-hydropower developments are then described. Present developments and future prospects are discussed, and requirements for the development of both local manufacture and scheme implementation are given.

Recommendations from each of the country study chapters are brought together in chapter 7. Comparisons are made between the countries with respect to their experience

with the manufacture of mini- and micro-hydropower equipment. Finally, proposals are made for the development of mini- and micro-hydropower schemes, and the future manufacture of small-scale hydropower equipment within each of the countries.

Chapter 8 presents the conclusions which are drawn.

CHAPTER TWO:
HYDROPOWER EQUIPMENT MANUFACTURE AND DESIGNS SUITABLE FOR THE CONDITIONS IN SOUTH-EAST ASIA

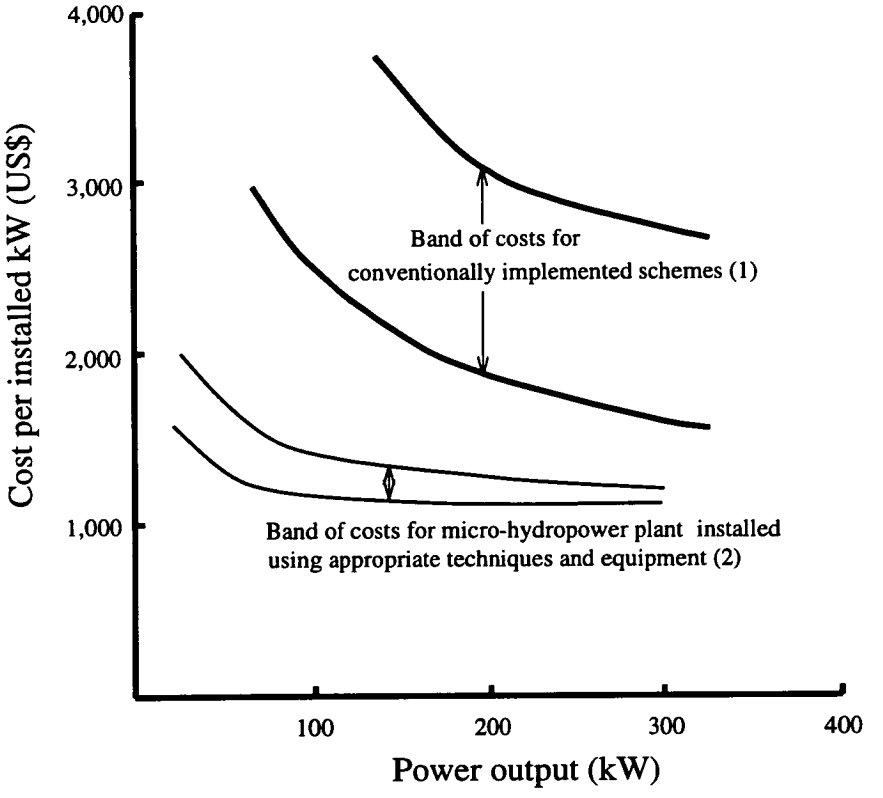
2.1. INTRODUCTION

Throughout the hundreds of years during which people have harnessed the power from streams and rivers, many different schemes and turbine designs have been used to accommodate the range from low-head sites on canals, to high-head sites in mountainous regions. As will be described in this chapter, designs vary considerably depending upon site conditions, such as the availability of head and flow rates, as well as other factors such as the accessibility to funds and the capabilities of the implementers.

It has been well documented that if mini- and micro-hydropower schemes are developed using the same construction and design approaches which are used for conventional large-scale schemes then the installation cost of a micro-hydropower schemes can commonly be as high as £5,000/kW (US$7,500/kW) [Wallace, 1990]. Schemes built in this way are often inappropriate in terms of size and complexity, as well as in other aspects such as project management. The viability of many projects in South-East Asia, as in many developing regions, is jeopardised by these high costs.

It has been shown that non-conventional approaches to management and construction can reduce costs drastically [Inversin, 1986]. Figure 2.1 compares the typical cost of schemes below 300kW built using conventional methods and cost reduction methods. Civil works costs, for example, can be reduced by as much as 25% by using community based construction approaches [Yadav, 1986], and the use of concrete pier and wooden stop-log weir designs instead of concrete mass civil works construction in Thailand have resulted in savings of up to 70%. Figure 2.2 shows cost details of two Thai schemes, one of which (Mae Thun Mini project) is the smallest scheme built as part of the country's mini-hydropower programme using techniques used for large schemes; the other (Mae Thun Noi) being the largest scheme constructed for the micro-hydropower programme, using low-cost weir and headrace construction techniques. The threefold difference in the cost of the two schemes can be seen to be primarily due to the different approaches taken in the civil works construction.

Civil works costs are generally the highest component cost for hydropower schemes, and as can be seen from figure 2.3, they are dependent upon the water head at the scheme. Low-head schemes generally require more substantial, and thus more expensive, civil



[Sources: 1 - Inversin, 1986; 2 - Holland]

FIGURE 2.1: Typical costs of micro-hydropower schemes per installed kW, as a function of installed capacity

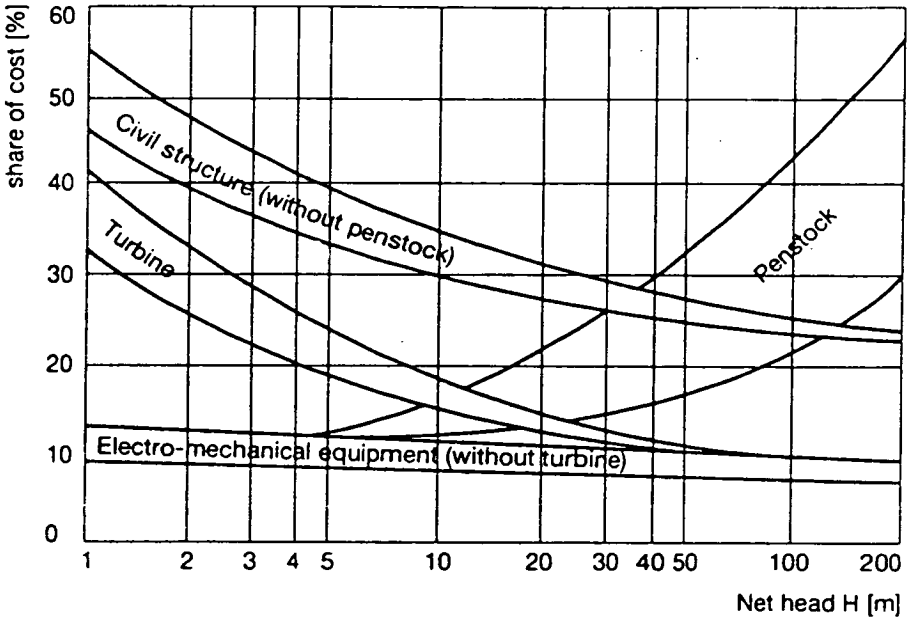
works structures than those required for high-head sites of similar capacity. It is common to find low-head schemes which use conventional construction methods to have a civil works/equipment costs ratio of 70%/30%, or reaching as high as 80%/20% in some cases [Yadav, 1986].

Non-conventional approaches can also be applied to the manufacture of powerhouse equipment, both in order to reduce costs and to match the equipment to the conditions for which it will be used. For example, equipment may need to be designed to be broken down in order to be carried to an isolated site by porters. In developing countries, equipment for micro-hydropower schemes generally needs to be of low cost, rugged construction, be suitable for straightforward installation, be easy to operate and require a minimum of maintenance. The situation is often very different in the case of mini-hydropower, where generating equipment efficiency is often of greater importance than initial cost, and skilled engineers are often available to perform operation and maintenance.

PROJECT	MAE THUN NOI	MAE THUN MINI
CAPACITY	250kW	250kW
HEAD	88m	65m
FLOW	500litres/s	485litres/s
WEIR TYPE	wood/concrete	concrete mass
WEIR COST	US$30,800	US$192,000
HEADRACE TYPE	lined canal, steel siphon	steel pipe encased in concrete
HEADRACE COST PER METRE	US$29.50/m	US$1970/m
TOTAL COST OF CIVIL WORKS	US$124,000	US$985,000
TOTAL COST	US$385,000	US$1,340,000
TOTAL COST/kW	US$1,540	US$5,350

[Source: Helling, 1986]

FIGURE 2.2: Cost comparison between two construction methodologies



[Source: Arter, 1992]

FIGURE 2.3: Share of total scheme cost by category, as a function of head

The situation varies from country to country, however, there are several major differences relevant to the manufacture of hydropower equipment in industrialised and developing countries†, as is shown in figure 2.4. In developing countries labour costs are generally low and thus locally fabricated equipment is in most cases cheaper than imported equipment. However, a trade-off often has to be made between this and efficiency, reliability and sophistication. Efficiency is often considered not to be so important at isolated sites which are not grid connected if power production is sufficient to meet the local demand. Cheaper powerhouse equipment will, however, not necessarily reduce overall construction costs, as reduced efficiency will in turn imply that greater flow rates are required, and thus civil work costs may increase.

Conditions prevalent in industrialised countries	Conditions prevalent in developing countries
Low price appreciated but not essential	Low price essential
Efficiency is important	Efficiency often has lower priority
Connected to the grid	Isolated sites more common
Wide availability of materials	Design restricted by materials availability
Wide range of machinery available	Few machine tools
Maintenance and repair easily possible	Maintenance- and repair-free design as far as possible
Easy access to site	Difficult access to sites, sometimes restricting equipment size and weight

[Source: Metzler, 1979]

FIGURE 2.4: Conditions affecting local manufacture of micro-hydropower equipment in industrialised and developing countries

The majority of mini- and micro-hydropower schemes in developing countries operate isolated from the grid supply, in contrast to the situation in industrialised countries where most are grid connected. In developing countries there is also a much greater use of schemes which directly drive mechanical devices, which are substantially cheaper as there is no need for a generator. Most micro-hydropower schemes will need to be started up and shut down manually in order to reduce equipment costs. This, however, increases the skills required of the operators. The use of components which require regular maintenance rather than expensive sealing arrangements can help to reduce costs, but this in turn may increase the likelihood of damage due to insufficient maintenance. In many cases the advantages of using cheap equipment will be outweighed by the disadvantages, particularly if the reliability and efficiency of the equipment is much reduced. This is particularly so if the equipment is to be used in an isolated area with difficult access and

† Countries are categorised as either industrialised, or developing, in accordance with the classifications used by the United Nations [UNDP, 1993] - see appendix D for the list of industrialised countries.

where there is a lack of skilled labour to maintain and repair the equipment.

Materials availability, technical capabilities of the workforce and the availability of machinery will all affect the equipment's design. The range of manufacturing capabilities required to produce equipment for a mini- or micro-hydropower scheme includes: welding, sheet metal fabrication, heat treatment, forging, casting, carpentry, and electrical and electronics assembly. These are available in most developing countries, however, in many regions manufacture is limited by such factors as: the lack of adequate test equipment; the poor quality of the raw materials; the lack of adequate machinery; the lack of know-how; and the lack of quality control procedures. These problems are not prevalent in all regions, and even where they are, local ingenuity has often overcome them. However, most countries attempting to establish local manufacturing capabilities have suffered from some of the following difficulties:

- poor reliability of equipment;
- low efficiency of equipment;
- variability of manufactured products;
- poor project management;
- inaccurate cost estimates.

Equipment produced in developing countries has typically had a shorter working life than those developed by companies in industrialised countries. This is often offset by the cost of domestically manufactured equipment being cheaper than the equivalent imported equipment, often by as much as 50% [UNIDO, 1983]. Also, in cases where certain components cannot be locally made, the assembly of the equipment within the country can also reduce costs drastically. For example, the cost of importing an Electronic Load Controller (ELC) in to Thailand from a supplier in the United Kingdom is over twice the cost of importing the component parts and assembling them in Thailand [Whitby, 1984]. This is principally due to lower cost of labour in Thailand, and also a reduction in the import duties and Value Added Tax (VAT) charges, as these are charged at a percentage of the worth of the goods at the time of import.

2.2. TURBINES

There are many manufacturers of hydropower equipment in developing countries. In most of these countries, however, companies have produced turbines only for micro-hydropower schemes, with far fewer having attempted to construct mini-hydropower equipment‡. Efficiency of equipment often becomes more important the higher the capacity of a scheme, and equipment of higher efficiency is more difficult to produce and is usually not available from developing countries. Thus there is still a need for the importation of powerhouse equipment to most developing nations with a mini-hydropower building programme. However, in many developing countries it has been possible to manufacture certain mini-hydropower turbine components, and to import those which are more difficult to produce†.

Typical costs for different types of micro-hydropower turbine are shown in figure 2.5. It should be noted that unit costs of the turbine are also dependent upon the head at a scheme, as shown in figure 2.3.

Capacity (kW)	Turbine costs per installed kW (US$)					
	Crossflow	Francis	Single-jet Pelton	Multi-jet Pelton	Turgo	Propeller
2	500 - 1,000	2,000 - 3,000	1,000 - 2,000	500 - 1,500	1,000 - 2,000	2,000 - 3,000
5	400 - 1,200	1,600 - 2,000	600 - 1,600	600 - 1,200	1,000 - 1,600	1,600 - 2,000
10	200 - 1,000	1,500 - 2,000	500 - 1,500	400 - 1,000	800 - 1,400	1,500 - 2,000
20	150 - 700	1,000 - 1,500	400 - 1,000	300 - 750	600 - 1,000	1,000 - 1,500
50	100 - 600	500 - 1,400	400 - 1,000	300 - 600	700 - 1,000	500 - 1,400
100	300 - 500	400 - 1,000	400 - 800	300 - 600	550 - 800	400 - 1,000
150	300 - 530	400 - 800	400 - 670	300 - 530	530 - 670	400 - 800

[Source: Fraenkel, 1991]

FIGURE 2.5: Typical cost of micro-hydropower turbines

It can be seen that in general, as the capacity increases the cost per installed kilowatt reduces. In some situations, however, cheaper manufacturing methods may be used at low capacities where there are lower mechanical stresses upon the equipment and when efficiency is not paramount, and thus beyond a certain threshold the cost per kilowatt of equipment may actually increase, as can be seen with the lower cost range of crossflow turbines in figure 2.5. As the capacity increases, these methods can no longer be used to

‡ It is important to realise that China, itself considered to be a developing country, produces more mini-hydropower equipment than any other country.

† For example, this has been the case in Thailand, as will be described in chapter 6.

produce effective equipment, and other more expensive techniques and materials are required. In most cases turbines are produced individually, however, where the demand for equipment is high enough to permit the batch production of standard equipment, costs can be reduced, as is the case in China. High-head sites generally have cheaper civil work structures than similar capacity low-head sites, as well as turbine costs typically being lower.

Material	Advantages	Disadvantages
Mild steel	Light Easily available	Corrodes easily Low strength
Stainless steel	Corrosion resistant	Expensive Difficult to work with
Cast iron	Material easily available	Heavy Brittle
Bronze	Hard material	Expensive Less readily available

FIGURE 2.6: Main advantages and disadvantages of the most common materials used in turbine manufacture

The type and complexity of the turbines which can be produced will depend upon the workshop facilities, skills and materials available, which will each have an effect upon the quality, reliability and efficiency of the equipment produced. Designs for equipment produced in developing countries thus need to be suitable for manufacture at local workshops, where machinery may be limited. Some components can be produced in a variety of different ways, using different materials and different manufacturing methods, whereas others are less accommodating. Over the centuries turbines have been made from many types of material including porcelain, wood, steel, bronze and plastic. The most common materials now used are mild steel and cast iron, whereas improvements in certain characteristics can be made using metal alloys, for example by incorporating either nickel or chromium to obtain improved anti-corrosion characteristics compared to that of standard mild steel. Figure 2.6 compares the characteristics of the materials used most often. The head and water quality can also have a bearing upon the best materials to use.

There are two distinct types of turbine: the impulse turbine, which is driven by jets of water impacting onto the runner; and the reaction turbine, which is totally submerged in water and is driven by the angular and linear momentum of the water. Figure 2.7

Reaction turbines	Impulse turbines
Submerged tailrace	Open tailrace
High specific speeds, allowing compact designs	Low specific speeds
High peak efficiencies	Lower peak efficiencies
Poor part flow efficiencies	Better part flow efficiencies
Use of draft tube to utilise head more fully	Lower runaway speeds
Higher runaway speeds	Reduced likelihood of cavitation occurring
Suffer from cavitation at reduced flow rates	Greater tolerance to sand and particles
Particles in the water more likely to cause damage	Less stringent sealing arrangements required
Require pressure seals around the shaft	Generally easier access to working parts
More complex maintenance requirements	Casings can be fabricated or cast
Casings needs to be accurately cast and strong	and accuracy of construction is less critical

FIGURE 2.7: Comparison between impulse and reaction turbines

compares impulse and reaction turbines with particular reference to their suitability to local manufacture. Impulse and crossflow turbines are generally simpler to manufacture than reaction turbines, and as such have been the type of turbine most often attempted by organisations beginning turbine manufacture. Reaction turbines are more difficult to fabricate, particularly in respect of the higher accuracy of machining required in order to produce a casing profile to tightly fit the turbine runner, and these are seldom made outside China and industrialised countries. Due to their higher specific speeds, reaction turbines are more suited to low-head schemes. Reaction turbines rely upon the water supply being very uniform, as their efficiencies fall rapidly as the flow rate is reduced below its optimum level. Run-away speeds are a higher percentage of the operating speed with reaction turbines than they are with impulse turbines, necessitating more robust generator designs and prohibiting the using of standard industrial generators.

Figure 2.8 shows the application range for the main types of turbines used for mini- and micro-hydropower, and summarises their applications, advantages, disadvantages.

2.2.1. Crossflow turbines

Also known as the Banki, Michell or Ossberger, the crossflow turbine functions as a hybrid between a reaction and impulse machine with approximately 90% impulse and 10% reaction components. The diagram in figure 2.9 shows the component parts of a crossflow assembly. Water passes through the rectangular cross-sectioned nozzle, twice striking the blades of the runner before flowing out through the draft tube.

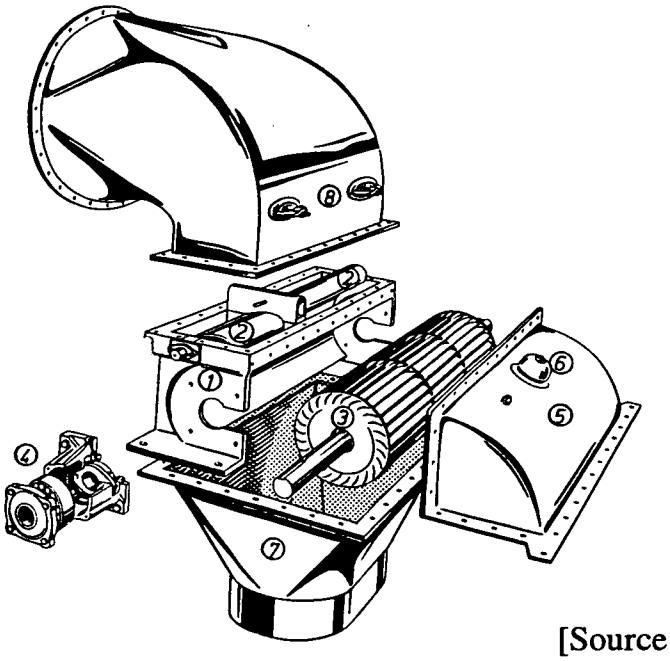
Turbine type	Applications	Advantages	Disadvantages
Crossflow	Specific speed range: 20 - 200 (SI units) Head: 3 - 200m Micro-hydropower only	High efficiency at low flow rates Designs easily available Simple to manufacture No casting required	Low peak efficiency Structurally weak runner
Pelton	Specific speed range: 5 - 70 (SI units) Head: 20 - 1,400m	Erosion damage easily repaired Small axial bearing loads High efficiency at low flow rates	Casting facilities required
Turgo	Specific speed range: 20 - 80 (SI units) Head: 15 - 300m	Good part flow efficiencies	High axial loading on bearings
Francis	Specific speed range: 55 - 500 (SI units) Head: 10 - 400m	High peak efficiency	Poor part load efficiencies More expensive than impulse turbines to manufacture Cavitation problems Casting facilities required
Kaplan	Specific speed range: 350 - 1100 (SI units) Head: 2 - 50m	Best part load efficiencies for a reaction turbine	Difficult to manufacture High runaway speeds
Propeller	Specific speed range: 300 - 900 (SI units) Head: 2 - 50m	Easiest reaction turbine to manufacture	Cavitation problems
Pumps-as -turbines	Specific speed range: 40 - 100 (SI units)	Low costs Readily available	Poor part load efficiencies Lack of application data Inadequate flow controllability

[Adapted from: Hothersall, 1984; Leyland Consultants Ltd, 1988; Fraenkel, 1991; Wallace, 1990]

FIGURE 2.8: Turbines for mini- and micro-hydropower schemes - applications, advantages and disadvantages

Although other turbines have higher peak efficiencies over the full range of the crossflow's application, the crossflow has other advantages such as its simple construction and high part-load efficiencies, as can be seen from figure 2.10. Relatively high efficiencies down to approximately 15% of full flow make them particularly useful where there are large seasonal water flow fluctuations. A single guide vane is used to provide flow control.

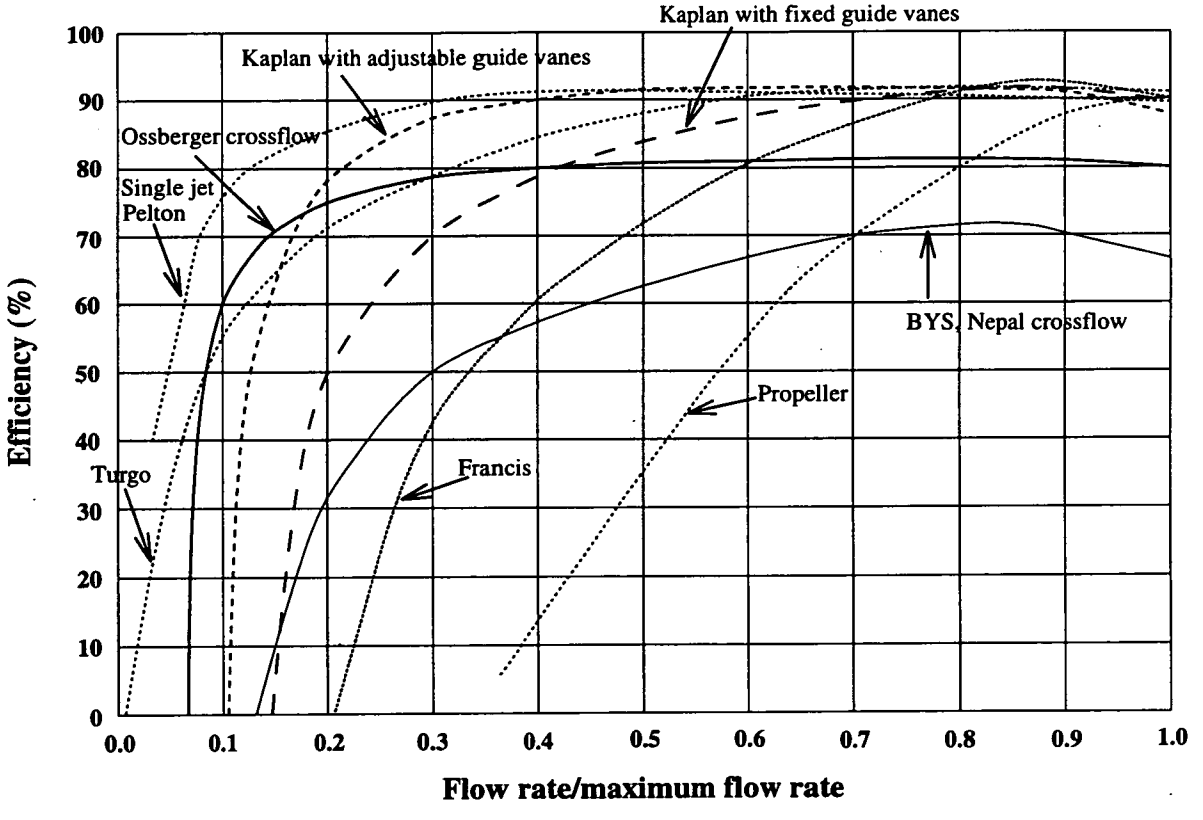
Virtually all crossflow turbines are built for the micro-hydropower range of capacities, either for low-head, or medium-head sites. At low-head most crossflow turbines require the use of gearing mechanisms in order to be coupled to a standard generator. This reduces both the efficiency and reliability of the unit, but they are still popular due to their



1. Casing
2. Guide vanes
3. Runner
4. Main bearing
5. Corner casing
6. Air inlet valve
7. Draft tube
8. Reducer

[Source: Ossberger]

FIGURE 2.9: A crossflow turbine



[Sources: Meier, 1985; Gilkes (b); Gilkes (c)]

FIGURE 2.10: Efficiency curves for some types of turbine

low cost. They have seldom been used for schemes in the mini-hydropower range or larger, mainly due to their lower mechanical strength, and also due to the fact that they experience stronger vibrations than other turbines, which becomes a serious problem at larger capacities.

Crossflow turbines are considered to be the easiest type of turbine to construct, and they can be produced even with very limited manufacturing facilities. There are approximately 25 major manufacturers of crossflow turbines world-wide [Arter, 1992], and most developing countries which are producing micro-hydropower turbines manufacture mainly crossflow, with the notable exceptions of China and Vietnam. There is considered to be an over-capacity of crossflow manufacture in the international market [Arter, 1992], but there is still scope for local manufacture of equipment in order to reduce costs for in-country schemes. Although construction manuals have been produced [Nakarmi, 1993; Inversin, 1980; Scheuer, 1980], the design knowledge needed in order to manufacture high peak efficiency turbines is restricted to only a few companies. Turbines produced with the information from published data generally only achieve efficiencies of up to 72% [Arter, 1992], in comparison to the over 80% efficiencies achieved by, for example, the German manufacturer Ossberger. As can be seen from figure 2.10, the difference in peak efficiency between equipment produced by Ossberger and those typically produced in Nepal is approximately 10%. These lower efficiencies are partly due to ineffective draft tube arrangements, and also due to not all water passing through the first stage of the runner, blockage at the first blades stage, and shock losses on entry to the second stage [Vo Sy Huynh, 1990]. Also, many schemes built from published designs generally suffer from a greater degree of cavitation and also from more structural failure of the runner blades than those designed from model tests.

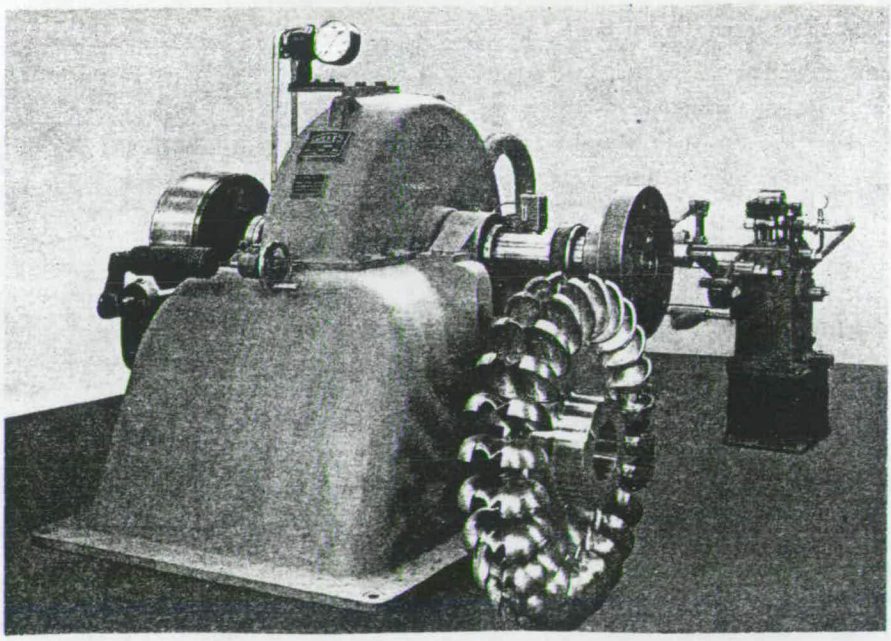
No casting is necessary for a crossflow turbine, and only basic workshop facilities† are required. In some instances where it is necessary to carry equipment by porters and there is no facility for welding on site, crossflow turbines have been designed such that parts can be bolted together and kept in position by taper pins. Blades are usually formed individually from mild or stainless steel, and welded into slots in supporting discs, however, whole runners can be cast as a single unit, resulting in higher strength. Welded equipment is generally lighter than cast equipment, which is particularly important where transport by porters is necessary. The simple symmetry of the crossflow blades also

† Basic workshop facilities as documented by SKAT [Meier, 1985] includes such machinery as a turning lathe, a drilling machine and boring attachment, a milling machine or shaper, an acetylene cutting torch or plate shear, arc welding equipment, specific jigs and fixtures, and general hand tools. Rolling and forging equipment are optional.

allows them to be fabricated by cutting pipe lengthwise, as well as by using a stamping press, or bending machine. Only the width of a crossflow turbine needs to be changed in order to produce a machine for different capacities, thus enabling standardisation of some component parts. This is restricted by increased metal fatigue with greater blade length, though supporting discs can be used to counteract this. Blade failures and poor design have probably contributed to the turbine's poor reputation in many countries. As the casing does not have large suction forces upon it, as is the case with reaction turbines, they are usually fabricated from mild steel sheeting. The rotor shaft is also typically made from steel, it either being drawn or machined from a block.

2.2.2. Pelton turbines

Pelton turbines are driven by jets of water impacting upon buckets positioned around a central disc, as can be seen from figure 2.11. They are used at medium- to high-heads for schemes throughout the micro- and mini-hydropower range. As can be seen from figure 2.10 they have a higher peak efficiency than crossflow turbines, and they tend to be more reliable due to reduced operational vibration, and increased strength of the runner, although these are also dependent upon the manufacturer's capabilities.



[Source: Gilkes, 1974]

FIGURE 2.11: A 475kW Pelton turbine and spare runner

Pelton turbine manufacture requires casting facilities, as well as welding, cutting and basic machinery for turning, planing and drilling. Runners may be cast in mild steel, stainless steel, bronze, cast iron, and even aluminium or plastic for small powers. In order to reduce corrosion, the choice of material and bucket design are most important, and mini-hydropower runners in particular require hard wearing, non-corroding materials such as nickel-chromium stainless steel, or a bronze alloy. Depending upon the capabilities of the manufacturer, as well as quality requirements, runners may either be cast as a single unit, or buckets may be cast individually and either welded or bolted on to a central hub. Single cast runners are the strongest, however, with individually cast buckets it is easier to finish the surfaces in order to increase the runner's efficiency. Individually cast runner buckets are usually welded rather than bolted onto the hub, the latter method only occasionally having been used for small micro-hydropower units. Bolted bucket designs have the advantage of being able to have a bucket, rather than the whole runner replaced if a bucket is damaged, but the stresses upon the bolts often cause failure and reduce the overall strength of the runner. The lost wax method‡ is often used for the intricate casting of a single cast runner, whereas individual buckets can easily be cast by the widely used sand-casting method. A large furnace is required to pour a mini-hydropower Pelton runner in one piece, the size being limited by the working diameter of the machinery available for finishing the casting. Runner efficiencies of over 90% can be achieved with skilled casting and a well profiled bucket pattern, however, even a basic design will produce efficiencies of over 80%, which may be sufficient for a micro-hydropower scheme [Waltham, 1992]. Most Pelton turbine manufacturers restrict the publicity of their bucket pattern design†, and in many countries designs have been obtained by preparing a pattern from an existing runner. Some attempts have been made to machine buckets from steel, however, they developed fractures after several months of operation [Meinikheim, 1977]. Similarly, buckets fabricated from sheet metal or pipe sections, have generally been unsuccessful [Inversin, 1986]. Again, efficiency is generally more important with higher capacity schemes.

In comparison to reaction turbines, the casing for a Pelton turbine is relatively easy to construct, requiring only cutting and welding facilities. However, other parts, including the rotor shaft, spear valve and other precision parts require accurate machining. Nozzles and spear valves are used in most Pelton turbines to control the water flow, the latter

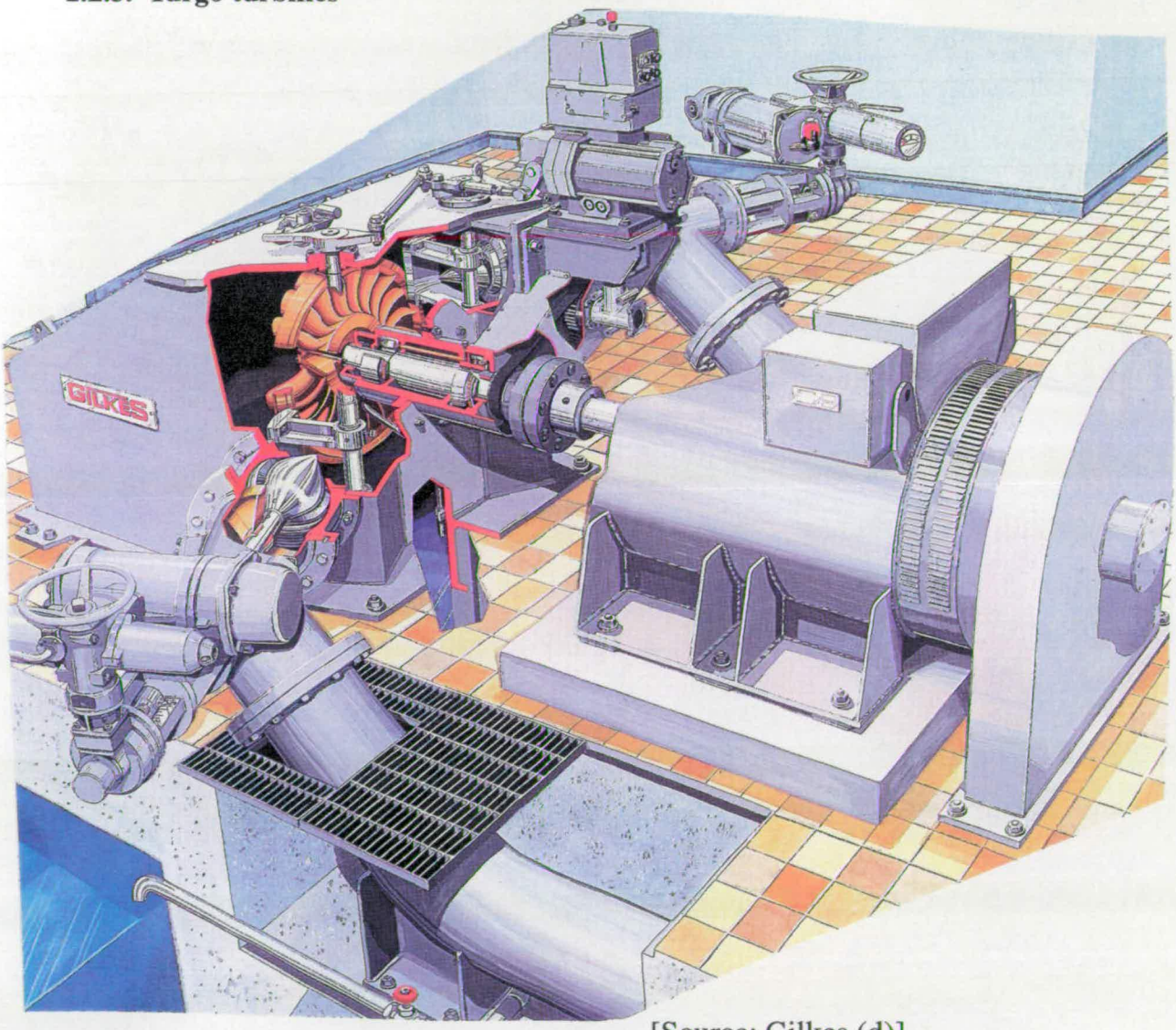
---

‡ A method of casting in which a wax pattern is placed between a two-layered mold and removed by melting and replacing the wax by molten metal.

† There is one publication available for a Pelton design with an efficiency of approximately 75% [Inversin, 1980].

representing a substantial portion of the equipment's cost. The nozzle, spear valve, spindle and curved deflector plate are often cast, although they need not be. Run-of-river schemes often operate best with more than one nozzle so that power may be generated efficiently at reduced flow rates. The cost of the nozzle for some very small micro-hydropower units has been reduced by just using a hole drilled through a sheet of metal [Inversin, 1986]. If a scheme is able to operate at a fixed power, for example with the use of an ELC, then it is possible to use a fixed nozzle, eliminating the need for a spear valve.

2.2.3. Turgo turbines



[Source: Gilkes (d)]

FIGURE 2.12: A turgo turbine

Turgo turbines were specifically designed for mini-hydropower schemes which required a specific speed between that of Pelton and Francis turbines, in order to enable direct coupling of the turbine and generator for a range of medium head applications. They have been produced in the United Kingdom and China, but very few other countries have

attempted to produce the turbine, partly due to the design information being withheld by the patent holders‡. Traditional Nepalese turbines have a very similar construction [Inversin, 1986]. The turgo has a slightly lower peak efficiency than that of the Francis turbine, but a higher part-load efficiency than the Francis, enabling it to operate at a wide range of flow rates. Unlike reaction turbines, the turgo does not suffer from cavitation action.

The complex curves of the turgo blade make them more difficult to fabricate than Pelton buckets, or crossflow blades, and they are also more fragile. Runners produced by the original turgo manufacturers are made from a single casting, using cast iron for lower heads, bronze or cast steel for medium heads and chrome-nickel stainless steel for high heads [Gilkes (c)]. Some attempts have been made by other organisations to make buckets from sections cut from steel pipe, welded between two steel bands, but these have generally not been successful [Inversin, 1986].

The casing can be either cast, or fabricated from steel using cutting and welding equipment. As with other turbines, the shaft is usually either forged or machined from carbon steel. The spear valve branch pipe is either made from cast iron, cast steel, or fabricated steel depending upon the pressure ratings, and the spear tip and nozzle are from stainless steel or bronze depending upon the head and quality of the water. Mini-hydropower schemes generally require more specialised components to be used. High axial thrusts developed by the water acting upon the runner require the use of thrust bearings.

2.2.4. Francis turbines

The Francis turbine is a reaction turbine, most suited to sites with a medium-head and a relatively high flow rate. Their efficiency falls rapidly as the flow rate is reduced from its maximum design rate, and at 20% of maximum flow there is effectively no power produced. As with all reaction turbines, cavitation can be a major problem. One further disadvantage is that the seals of a Francis turbine need to be replaced regularly.

Figure 2.13 shows a Francis turbine installed in Thailand (and figure 4.19 shows a Vietnamese-made Francis runner). The Francis turbine can either be horizontally mounted, or vertically mounted, however, for mini- and micro-hydropower horizontal mounting is universally used. The advantages of this for small Francis turbines are the

‡ Gilbert, Gilkes and Gordon Ltd, Kendal, United Kingdom.

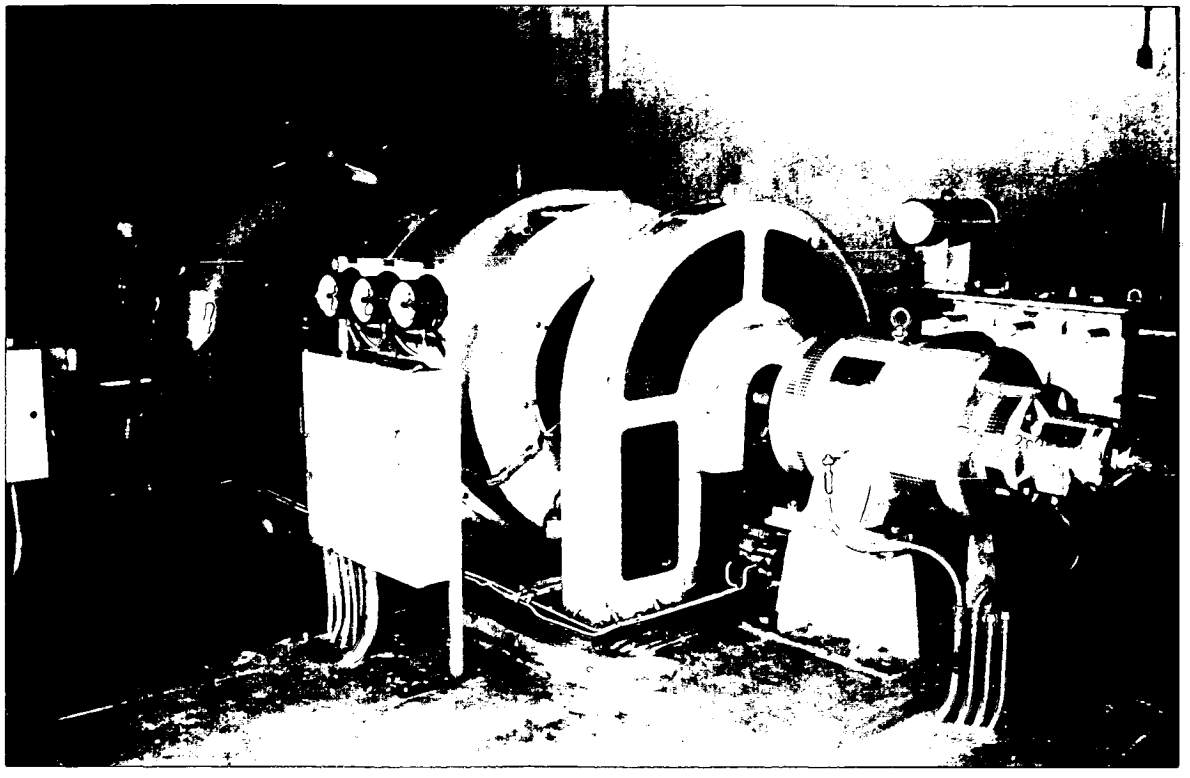


FIGURE 2.13: A 650kW Chinese Francis turbine installed in Thailand

easier mounting and dismounting of turbine and generator, and the availability of standard generators.

Both the runner and the turbine casing require complex and accurate castings, and for this reason the more simple crossflow turbine is generally used in most micro-hydro applications, even in cases where drive-belts are then required. Notable exceptions to this occur in China, where crossflow turbines have seldom been used and Francis turbines have been used for micro-hydropower applications. For mini-hydropower and greater capacities the use of drive-belts is not feasible, and the higher efficiencies of the Francis make it a viable option in many situations. The Francis runner is usually a one piece casting of stainless steel or bronze, however, other materials including cast iron, and chrome-nickel stainless steel are also used [Gilkes (a)]. The turbine housing usually consists of a cast split casing to ease bearing and seal replacement. With small units the casing may be fabricated from steel. The draft tube is an important part of all reaction turbines, and can be either cast or fabricated from steel.

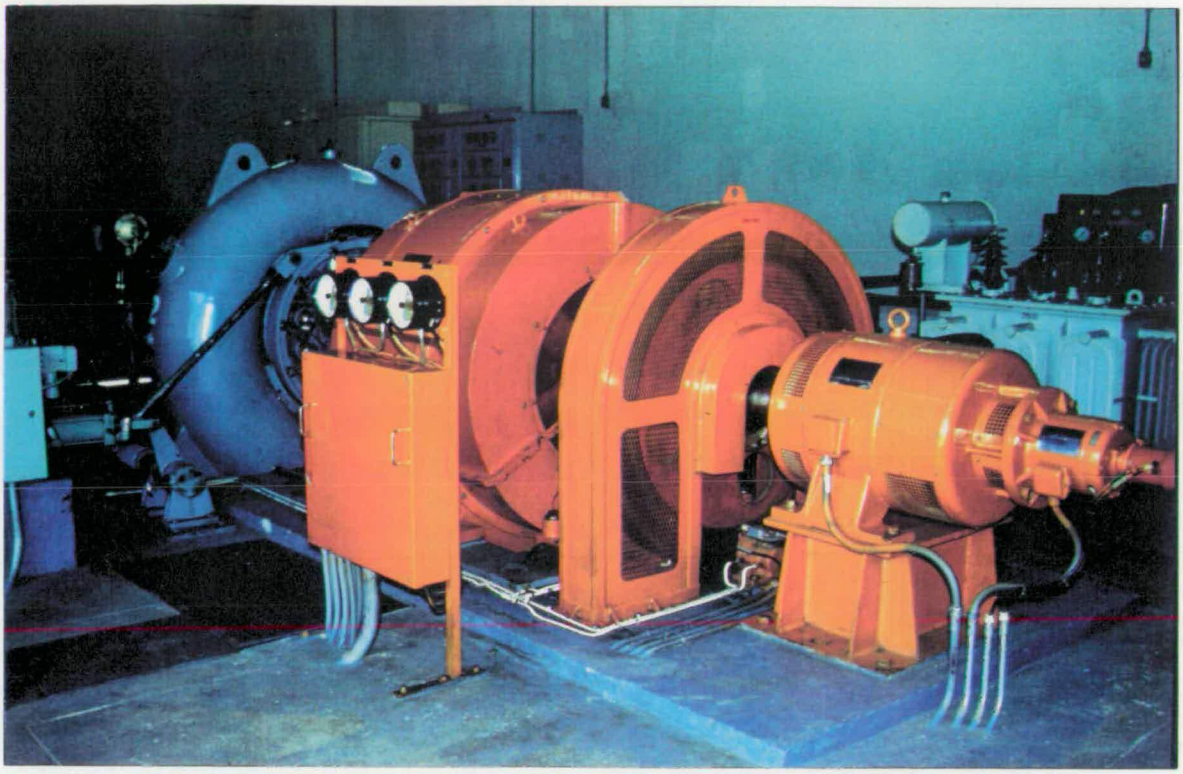


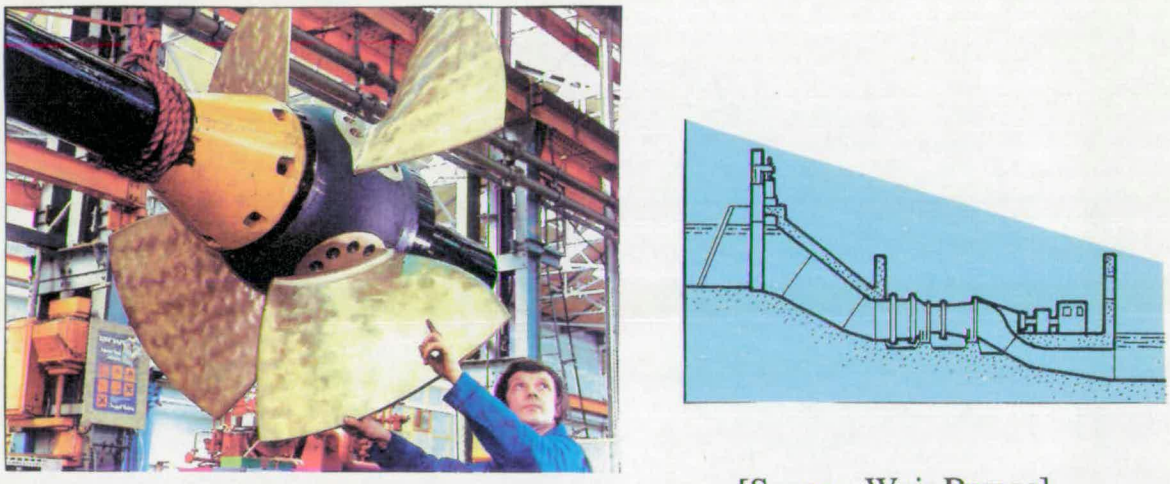
FIGURE 2.13: A 650kW Chinese Francis turbine installed in Thailand

easier mounting and dismounting of turbine and generator, and the availability of standard generators.

Both the runner and the turbine casing require complex and accurate castings, and for this reason the more simple crossflow turbine is generally used in most micro-hydro applications, even in cases where drive-belts are then required. Notable exceptions to this occur in China, where crossflow turbines have seldom been used and Francis turbines have been used for micro-hydropower applications. For mini-hydropower and greater capacities the use of drive-belts is not feasible, and the higher efficiencies of the Francis make it a viable option in many situations. The Francis runner is usually a one piece casting of stainless steel or bronze, however, other materials including cast iron, and chrome-nickel stainless steel are also used [Gilkes (a)]. The turbine housing usually consists of a cast split casing to ease bearing and seal replacement. With small units the casing may be fabricated from steel. The draft tube is an important part of all reaction turbines, and can be either cast or fabricated from steel.

2.2.5. Propeller turbines

For low-head sites, propeller and other axial turbines are the most effective option due to their high specific speed. There are two main type of propeller turbine, those with fixed blades, and those with adjustable blades, known as Kaplan turbines (as shown in figure 2.14). The Kaplan's movable guide-vanes and variable pitch blades make the unit considerably more expensive than a fixed bladed propeller, and this level of sophistication is usually prohibitively expensive for micro-hydropower, however, the increase in efficiency at reduced flow rates makes them more viable in the mini-hydropower range. With fixed blades, the efficiency of a propeller turbine falls quickly with reduced flow rates.



[Source: Weir Pumps]

FIGURE 2.14: A 2.2MW Kaplan runner and site schematic

Kaplan turbines have more demanding manufacturing requirements than propeller turbines, due to the need for a mechanism to adjust the pitch of their blades, and they are subsequently more expensive. In both cases blades are usually cast, however, it is possible to form them from steel plate. Blade profiles need to be well designed to reduce cavitation and obtain high efficiency. The casing, guide-vane assembly, and draft-tube can all be fabricated from steel sheet [Inversin, 1986].

2.2.6. Pumps-as-turbines

Using a pump as a turbine has recently become more common, as cost savings can be as much as 60% over an equivalent turbine [SHP News, 1993]. Pumps are cheap in comparison to turbines as they are mass produced in large quantities, and they are readily

available in a wide range of standard sizes up to ratings of 100kW. Their major disadvantages are that when used as turbines their peak efficiency is generally around 70% [SHP News, 1993], and efficiency falls rapidly when operating below optimum flow rates. The reduced peak efficiency may lead to reduced cost effectiveness, but in settings where the hydropower potential is much greater than the demand, and keeping to a low installation cost is of prime importance, then using pumps-as-turbines can be the best option. Other problems of pumps used as turbines are their high susceptibility to suffer from cavitation, and the difficulty in predicting a pump's characteristics. They also need both constant drive and load conditions, as it is not practical to control them hydraulically. They are only suitable for small micro-hydropower applications.

2.2.7. Other turbines

For countries with extensive irrigation systems other types of low-head turbines may be used, but they are generally too costly for most micro- and mini-hydropower schemes. Rim generators and bulb-type turbines have high efficiencies, but they all require complex sealing arrangements, and are not considered to be suitable for small schemes.

In-stream water-current turbines are being investigated for regions where only small quantities of power are required near to rivers with large flows, making it infeasible to construct large civil works. They are considered to be effective at pumping water for irrigation purposes, but as yet only demonstration projects have been established to produce electricity.

2.3. GENERATORS

Both synchronous and induction generators are used for mini- and micro-hydropower schemes, and an increasing number of countries are developing the skills necessary in order to produce the equipment. Locally produced equipment is generally cheaper than imported equipment: for example, Indian generators are approximately one-third of the cost of imported generators. The cost of equipment varies widely, being dependent upon size, type, quality, application and manufacturer. Price and availability are generally the most important factors in deciding which type of generator to use for a micro-hydropower scheme, whereas efficiency and reliability generally become more important with larger equipment.

2.3.1. Synchronous generators

Synchronous generators are the most commonly used type of generator for micro- and mini-hydropower applications, and they are the only type of generator used at mini-hydropower sites which are not connected to a grid system. Synchronous generators are more complicated and expensive than induction generators, however, small 1500rpm and 1000rpm synchronous machines are still relatively cheap, as they are mass produced for diesel generators. Three-phase units are most commonly used, however, they are generally not available below 2-3kW, and single phase units are usually used for micro-hydropower schemes with capacities up to 10-15kW. This is due to the difficulty of obtaining a balanced three-phase load at low capacities for a village electrification system, and although the cost of a single-phase unit is similar to that of a three-phase unit for small capacities, the three-phase generator will require costlier monitoring, control and switchgear.

There are three main types of excitation systems for a synchronous generator - shunt excited, separately excited and brushless. Slip rings and brushes require regular maintenance, and are one of the weak points of the former two types of system. Brushless alternators are more expensive and less readily available, however, by relinquishing the need for slip rings and brushes the maintenance requirement is reduced. A generator needs virtually no maintenance if it is brushless and the bearings are sealed. This is important for geographically isolated schemes, but these advantages must be set against the associated increase in price for this type of generator. They use a rotating diode configuration which is generally more difficult to construct than the other two configurations.

All synchronous generators operating in isolation from the grid require an Automatic Voltage Regulator (AVR), which controls the rotor field current to keep the generated voltage approximately constant. For smaller generators, the AVR is usually a single printed circuit board connected in the terminal box or at the end of the generator enclosure, and on larger machines they are placed in the control cabinet [Energy Systems Group, 1987]. They cost upwards of US$300, thus adding considerably to the cost of a small unit, but this is generally an insignificant percentage of the cost of a mini-hydropower system.

Generator manufacture is considered to be more difficult then turbine manufacture, and as such many turbine producing countries import the generators required. Laminated sheets, copper wire and insulating materials are all needed for generator production. Humidity,

elevation and ambient temperature all effect the design of a generator, and thus locally manufactured equipment can readily be adjusted to suit the local environment. Manufacture requires equipment for winding coils, welding and cutting as well as dynamic balancing test equipment. The stator for synchronous generators require laminated sheets of steel to be welded into a cast or fabricated steel barrel. Varnish insulated copper wire wound around the rotor is impregnated further with electrical varnish and baked in order to achieve bonding and high dielectric strength.

Many countries which have imported diesel generator sets in the past are reconditioning these particularly for use in micro-hydropower, and in some cases mini-hydropower schemes. Most diesel generator sets fail due to faults with components outside the generator itself, and thus the generators are often in good condition. However, they do require adjustments to be made in order for them to be suitable for use in hydropower schemes. Turbine generators need to be designed to withstand larger centrifugal forces than those designed for diesel generation, as unsupervised hydropower units may over-speed at up to 200% of their operating speed for many hours. Generators used in diesel sets are not designed for this, and thus the rotor windings must be mechanically clamped in order for them to be able to withstand these possible conditions. The bearings must also be upgraded, particularly if a turbine which creates axial thrusts is used, however, thrust bearings can be incorporated in the turbine design. If the generator is to be directly coupled to a turbine, then the generator could be supported by the turbine shaft bearings usually in conjunction with the single bearing of the adapted generator. If, however, the generator is not to be directly coupled then a stub bearing would need to be fitted. Ideally the generator casing would also be strengthened, however, in Vietnam this does not appear always to be undertaken. Their use is also limited by the fact that most generators from diesel generator sets are either two- or four-pole machines, and therefore they may only be used in situations where the site conditions and turbine are suitable such that these 3,000 rpm and 1,500 rpm generators are suitable. If, for example, a site with a low head is to be fitted with an impulse turbine (perhaps as they are the only types of turbine being manufactured locally), then an eight-pole generator may be needed if the use of gearing is to be avoided.

2.3.2. Induction generators

Induction generators are easier and significantly cheaper to construct than synchronous generators up to approximately 40kW [Smith, 1990], and as induction motors are mass produced for industrial uses, they are readily available in most countries in a wide range of capacities. They are used principally at grid connected schemes, however, due to the

large reactive current which they require from the grid to magnetise the machine, they are seldom used in grid connected rural electrification schemes at a long distance from the next nearest power scheme. They have the advantages of having lower costs and there being no requirement for synchronising equipment or excitation equipment, as there is with synchronous generators. For example at a 1MW scheme in Thailand the overall cost of the electrical plant was reduced by 15% by using an induction generator rather than a synchronous machine [Chulapongs Chullakesa, 1991 (b)]. In the range below 10kW, induction generators are approximately one third of the cost of synchronous generators [Smith, 1990]. The majority of units used for isolated schemes with variable loads have been of capacities below 40kW. Until recently they have been considered to be inappropriate for use at isolated sites due to the difficulty in controlling their frequency and voltage when external excitation is not available. In some cases small units were used with fixed loads to avoid this problem, however, this created problems for the users of the supply. The recent development of a governor to control small induction generators with a varying user load has enabled them to be used for low capacity, isolated, rural electrification projects [Smith, 1990], but as yet their use in such situations is still in a state of development.

Restrictions:

In isolated schemes, only used up to approximately 40kW
Only suitable for resistive loads
In most cases requires the use of an electronic load governor

Advantages if restrictions are met:

Less expensive
Greater reliability
Virtually maintenance free
More robust
More resilient to prolonged overspeed

FIGURE 2.15: Advantages of using induction generators instead of synchronous generators for isolated schemes

The rotor of an induction generator consists of cast aluminium or copper bars, making it more robust and requiring less maintenance than the rotor of a synchronous machine, with its windings, diodes, or slip rings and brushes. Over-speed of 200% of name plate speed can be withstood without adaptions needing to be made to the rotor for off-the-

shelf units. One of the disadvantages of using induction generators is that they need power factor correction with inductive loads, otherwise loss of excitation may result.

2.3.3. Other generators

Where only small quantities of power are used in remote rural areas, batteries are used to store electricity for lighting and other low capacity appliances. If an a.c. supply is not also required, then a d.c. generator can be used. Although it is possible to use an inverter to obtain a.c. from d.c., the extra expense is usually prohibitively high for a rural low income community. Small d.c. generators are available from cars and trucks, and are relatively inexpensive, but have poor efficiency, and brush and commutator wear problems. Industrial d.c. motors with permanent magnet rotating fields have good efficiency and are reliable, but they are more expensive than car alternators, and still have brush and commutator wear problems.

2.4. GOVERNORS

There are two main types of governor, flow control and load control, each having advantages over the other for different applications. The flow control governor comes in many forms, all adjusting the flow of water to adapt to the varying loads on the system. Until the 1980's these were the only form of automatic governor available, but their cost and complexity prohibited them from being used for small micro-hydropower schemes, resulting in the situation whereby many sites only have the provision for manual governing.

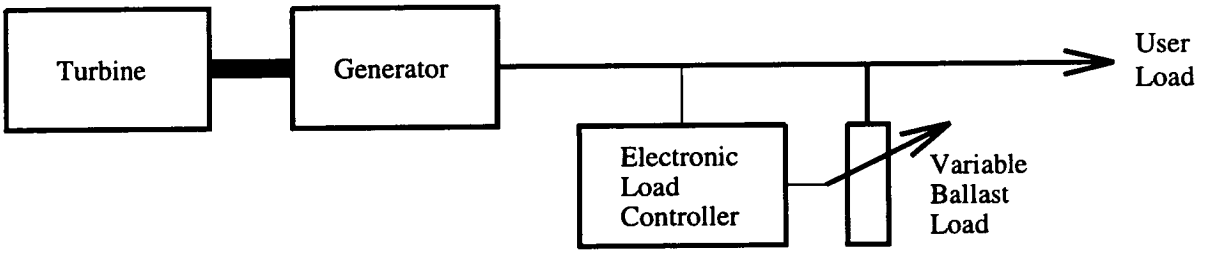


FIGURE 2.16: A schematic diagram of an ELC

The Electronic Load Controller (ELC) uses a different principle, whereby the total load upon the generator is kept approximately constant when users adjust their power consumption, by varying a ballast load. This can be achieved either by adjusting the number of resistive components connected in the ballast load, or alternatively by phase

control using a single resistive load. Figure 2.16 shows a schematic diagram of and ELC, and figure 2.17 shows the main advantages and disadvantages of ELCs over flow control governors. This type of governor is not suitable for schemes with large capacities as it becomes increasingly more difficult to reliably dissipate the the surplus energy. Also, where a scheme has been designed with a reservoir and water is in short supply, a system using this type of governor has the disadvantage of not being capable of reducing water usage with a reduction in power demand.

ELC advantages compared to flow control governors
Considerably cheaper
Simpifies the turbine, reducing its cost
Load factor is improved if the ballast load is used productively
Easier to install
Responds faster to changes in load
Minimises surges in the penstock
Has improved reliability
Reduced maintenance requirement
ELC disadvantages compared to flow control governors
Not suitable for sites where water conservation is important
Typically only used at sites with capacities below 50kW
More difficult to repair unless replacement of a module is sufficient
Requires electronic manufacturing capabilities

FIGURE 2.17: Advantages and disadvantages of using ELCs rather than flow control governors for micro-hydropower sites

The development of the ELC, which can be manufactured for as low as one-tenth of the cost of a conventional mechanical-hydraulic governor [Henderson], has enabled many small micro-hydropower sites to have an automatic governing system. ELC manufacture requires an electronics workshop, however, several countries are assembling the components which are supplied from abroad. In Thailand local assembly of ELCs has provided a cost saving of more than 50% over the import of completed units, and a similar reduction over the cost of a popular imported Chinese hydraulic governor [Whitby, 1984]. The use of an ELC can also simplify the design of other components of the plant. For example, if an ELC is used, spear valves are not required for Pelton turbines, the need for movable guide vanes for reaction turbines is removed, as is the need

for a flywheel. These benefits are not always appreciated, and thus many schemes are over designed, as has been the case in Thailand. ELCs require a high degree of technical knowledge to design them, but maintenance can be made simple with the use of plug-in modules, and with no moving parts they require much less maintenance than a flow control governor. An additional advantage of the ELC is that the penstock is likely to experience fewer pressure surges and thus their costs can sometimes be reduced.

In the mini-hydropower range, flow control using mechanical-hydraulic, or electrical-hydraulic governors are used exclusively. Electrical-hydraulic governors sense shaft speed electrically, then alter the rate of flow of water in order to keep this constant, whereas mechanical-hydraulic sense the same changes in speed usually by means of a fly-ball mechanism. Mechanical-hydraulic governors are complex, comparatively unreliable, are difficult to repair, and can represent a significant proportion of the total cost of equipment, even for mini-hydropower schemes, and are prohibitively expensive for most micro-hydropower developments. Figure 2.18 shows the type of Chinese mechanical-hydraulic governors which have been used for mini-hydropower schemes in Vietnam. Manufacture of hydraulic governors on a commercial basis in developing countries has seldom been effective (except for in China) [UNIDO, 1983], and the need to use precision machine tools prohibits many companies from attempting to produce them. Electrical-hydraulic governors are considered to be easier to construct if electrical workshop facilities are available.

Where ELCs are not available, manual control has often been the most economical option for low capacity sites in the region of 50kW and below, in areas where the cost of employing an operator is low. Eighty percent of micro-hydropower schemes worldwide are thought to be manually controlled, either due to design, or by fault of the governing system [Minnot, 1981]. Operators, however, are not typically as fast as automatic governing mechanisms, and a system with manual control is often likely to experience wide voltage fluctuations. Also, a lack of understanding concerned with the operation of the manual governing mechanisms has sometimes led to burst penstock. Constant load schemes have been developed in order to eliminate the need for a governor, but in rural electrification settings this has often been ineffective as, for example, customers are required to keep their lights on all of the time, yet customers have often been found to remove bulbs, thus disrupting the system.

The Induction Generator Controller (IGC) developed by Smith [Smith, 1990], controls voltage and frequency of an induction generator using a ballast load. It is similar to the ELC, and of a comparable price. Very few of these governors have been made as yet.

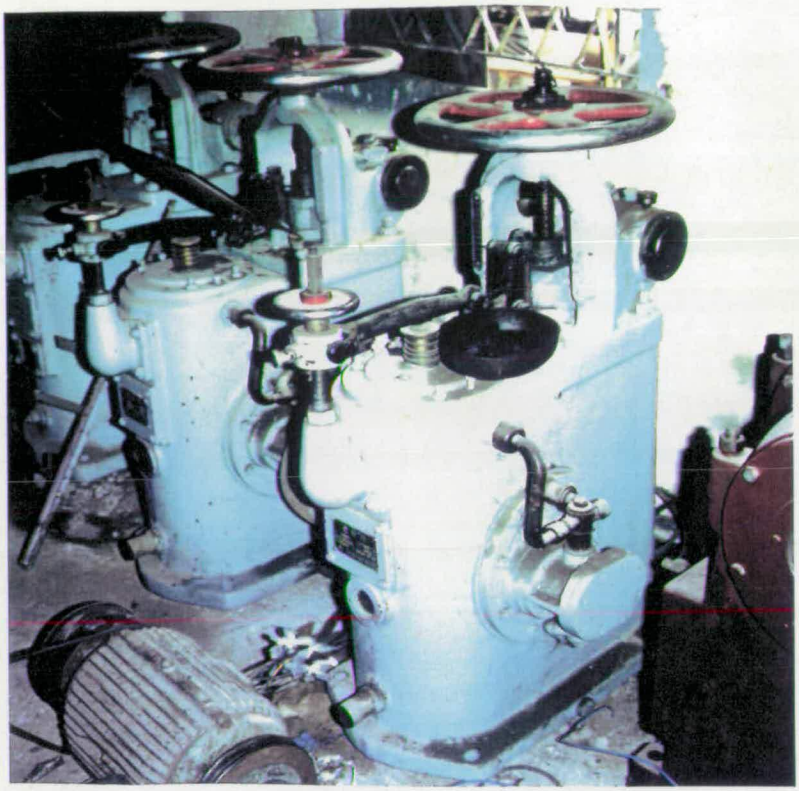


FIGURE 2.18: Chinese mechanical-hydraulic governors used in Vietnam

2.5. INTEGRAL TURBINE AND GENERATOR SETS

The demand for low capacity equipment which is both cheap and easy to install has led to the development of units incorporating a directly coupled turbine and generator which can be bought off-the-shelf. The turbine and generator are aligned at the factory, making installation much simpler. These units are typically for electric power outputs of between 50W and 5kW, for both low-head canals and medium-head, ultra low volume flow rate sites.

2.5.1. Family-hydropower

Family-hydropower installations, which comprise of a turbine and generator with a capacity of between 50W and 2kW, are being used in parts of China and South-East Asia. They have the advantages of having a low purchase price, and of being capable of being installed by villagers with little or no outside assistance. Often the site conditions available are not used to their greatest capacity, but the advantages of not having to rely upon distant organisations or engineers normally outweigh the disadvantages. They can be purchased in the market place for as little as US$28 for a turbine and generator which

will supply in the region of 80W. They are principally used for lighting, usually providing 220V a.c., but occasionally a unit also has a 12V d.c output which is used in conjunction with a battery, and subsequently used for different electrical appliances.

Many standard capacity units are produced for both low-head and medium-head sites. The most popular models are those with capacities in the range 100W to 200W, requiring a 1.0 - 2.5 metre head to provide a 220V a.c. output. In comparison to the 1kW model, the 100W and 200W models have a lower efficiency and higher cost per unit of installed capacity, but as low initial price is often the most important factor to low income families, they have been more popular than larger units. Figure 2.19 shows the cost comparison for some of the different types of equipment available. The Chinese equipment is often rated at a higher capacity than the equipment can actually deliver, and there have been many reports of Chinese Family-hydropower units being mechanically unreliable [pc: Nguyen Duc Loc (a)].

TURBINE TYPE	ORIGIN	POWER (W)	HEAD (m)	FLOW RATE (m^3/s)	PRICE IN VIETNAM (US$)
PROPELLER	CHINA	100	1 - 2	0.015	28
PROPELLER	VIETNAM	200	1.5 - 2.5	0.020	75
TURGO	CHINA	250	6 - 15	0.005	32
PROPELLER	CHINA	300	1.5 - 2.5	0.020	280
PROPELLER	CHINA	700	2 - 3	0.050	420
PROPELLER	VIETNAM	1,000	2 - 4	0.080	350

N.B. Prices do not include draft tube, or penstock.

FIGURE 2.19: Price of some Family-hydropower equipment from Vietnam and China

The Chinese equipment comes in two forms, one using a fixed blade propeller with guide vane as shown in figure 2.20, and the other using a turbine similar to a turgo. Often bamboo is used as piping for the latter model, which requires a head of six to fifteen metres. The generators are six-pole permanent-magnet machines, providing a 220V a.c. supply. Most Family-hydropower units have no governing or protection devices, and thus the voltage varies greatly with the load. However, a flow regulator is provided with the turgo machine, and a single-relay ELC device provides approximately 30% extra loading via a water-cooled ballast on the 1kW unit.

2.5.2. Other integral, low capacity units

Many different low cost approaches have been used, including attaching a Pelton runner on to the shaft of an induction generator, which has proved to be cheap and robust†.

† The "Peltric" unit [Waltham, 1992].

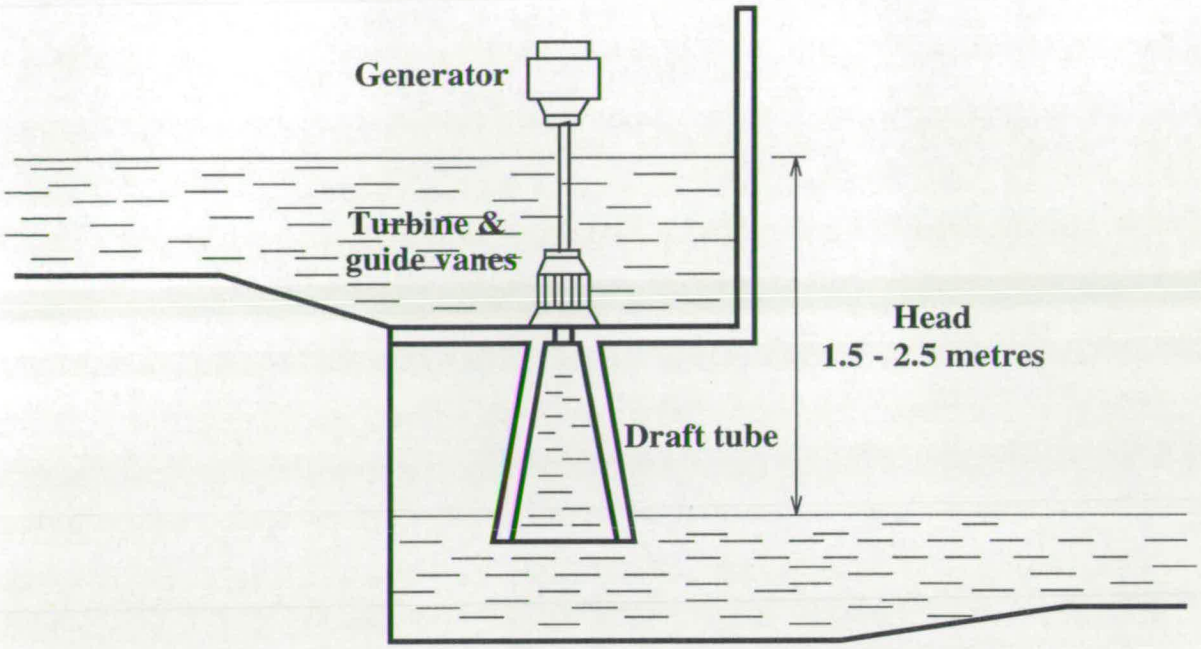


FIGURE 2.20: Schematic diagram of a 200W Family-hydropower unit



FIGURE 2.21: Three 100W Family-hydropower units being used on an irrigation canal in Vietnam

Mounting the turbine runner directly onto the free end of the generator shaft eliminates the need for a separate turbine shaft and bearing, however, the generator bearings must be capable of withstanding the thrust forces exerted via the turbine.

Battery charging units consisting of a very small Pelton runner driving a car alternator have been produced in several countries. In the United States of America a single nozzle Pelton unit capable of producing 500W is sold for US$695, excluding penstock. The runner is cast from silicon bronze and is stated to have a peak efficiency of 90% [Harris Hydroelectric].

2.5.3. Batteries

Most of these integral sets generate electricity for lighting, either directly, or via the use of storage in the form of a battery. Lead-acid car batteries are readily available in nearly all regions of the world, but regular deep discharge of these batteries, which often occurs when used in a rural electrification setting, drastically reduces their working lives. Sealed lead acid batteries need less maintenance, but are more expensive and are generally harder to obtain [Cromwell, 1991]. Manufacture of low capacity batteries has been successfully undertaken in several countries. They have been used particularly for lighting purposes, with their low cost being their most successful attribute.

2.6. OTHER EQUIPMENT

2.6.1. Drive mechanisms

Very low speed generators tend to be large, expensive and not available with ratings in the mini- or micro-hydropower range. Therefore some method of speed increaser is often required in order to use both standard generator and compact turbine equipment, particularly with low capacity impulse or crossflow turbines. There are many forms of frictional drives and positive drives, as well as direct coupling. In figure 2.22 the main types are compared in terms of their manufacturability and suitability to different conditions.

2.6.2. Bearings

The bearings used in mini- and micro-hydropower equipment need to be hard wearing and long-life. Along with problems with the runner, bearing problems are the most common source of faults in a turbine. Self-lubricating bearings alleviate the burden of

Drive mechanism	Efficiency	Advantages	Disadvantages
Direct coupling	98% - 99%	Low cost Avoids efficiency losses Requires minimal maintenance Compact No bending moments No radial loads on bearings	Turbine - generator alignment is more critical Increased damage if generator or turbine lock up
V-belt	85% - 95%	Widely available Tolerates misalignment Most common up to 100kW	Large powers require multiple belts Less tension than with flat belts Lower efficiency than other drives
Flat belt	95% - 97%	Low cost Easy to produce Readily available Less rubber dust than V-belts	Operates under high tension High loads upon bearings Requires careful alignment Less available than V-belts in many places
Chain drive	98%	Long life No slippage High efficiency	Low availability Requires lubrication High cost
Gear box		High power transmission capabilities	Difficult to manufacture High cost Alignment problems Requires lubrication
Timing belt	98%	High efficiency Little lubrication required Low belt tension	High cost Low availability

FIGURE 2.22: Comparison of drive mechanisms for micro-hydropower equipment

Roller bearings	Sliding bearings
Relatively expensive	Comparatively cheap
Require clean grease	Large amounts of lubricant required
Most are not sealed allowing dirt ingress	Longer life than rolling element bearings
Poor self-alignment in ball bearings	High friction upon starting

FIGURE 2.23: Comparison of the bearings used in hydropower equipment

regular maintenance and avoid the possibility of the ingress of dirt or over charging, but are generally more expensive and are not often made in developing countries. Figure 2.23 compares the use of roller and sliding bearings. The use of self-aligning spherical double-roller bearings make accurate machining of the bearing supports unnecessary, thus making the manufacture of other component parts less complicated. Water lubricated wood bearing material is sometimes used.

2.6.3. Penstocks

Many different types of material are used for penstock, and their suitability to a particular project will depend upon the availability and cost of the materials, as well as qualities such as roughness which affects losses, requirements for fabrication and ease of transport. Figure 2.24 compares the different types of material used for penstock, and highlights those most suitable for local manufacture. Mild steel is the most widely used material, as it is relatively cheap, usually readily available, may be locally fabricated, and has good resistance to mechanical damage. It is, however, vulnerable to corrosion. High density polyethylene and uPVC have in many cases replaced steel as they are cheaper and lighter, and have excellent corrosion resistance. However, at higher pressures and for larger diameters, steel pipe still has an economic advantage over plastic pipe [SHP News, 1990 (a)].

2.6.4. Flywheels

Flywheels are used in hydropower schemes to help maintain the frequency of operation during the time taken for the governor to adjust to changes which occur in the system load. They may be cast or fabricated, and are relatively simple to manufacture.

2.6.5. Valves

Casting capabilities are required to manufacture valves. Cast steel is better at withstanding high pressures than grey cast iron valves which have poor pressure performance, this, however, is not so important for mini- and micro-hydropower equipment. Their manufacture is often geared to a wider market than solely the hydropower market, as the same designs can be used.

2.6.6. Instrumentation

The monitoring, protection and switchgear equipment used at a hydropower scheme will vary depending upon the needs placed upon the scheme and the resources available. The basic instruments required include frequency, voltage and ampere meters, and protection devices for overcurrent, overspeed, over/under voltage, and phase imbalance. These require expert skills, know-how and machinery to produce them, and in most cases this type of equipment is bought from abroad. For a country beginning to develop its hydropower equipment manufacturing capabilities, these are the components which in the short term are the least advantageous to manufacture locally, unless they are required for

Material	Advantages	Disadvantages
Steel	Easily available in most places Very strong Reasonably easy to make bends Reasonably easy to repair	Requires welding facilities on site Relatively heavy Surface suffers from deterioration Requires moderate maintenance High installation costs
Cast iron	Durable Long life expectancy	Very heavy Expensive Very difficult to repair Brittle surface Smoothness deteriorates with time Difficult to make bends
Pre-stressed concrete	Low cost Durable Easy to install Good water sealing of joints Low maintenance costs	Breaks easily Not always available
Concrete	Durable Cheap Can be made locally Easily repaired	Heavy to transport Poor hydraulic performance Bends are difficult to create
Asbestos cement	Low cost Easily installed Durable Smooth	Relatively heavy and fragile Needs to be buried High health risk with manufacture Affected by acid soils
uPVC	Low cost Light weight Rapid installation Very smooth surface Easily repaired Good resistance to corrosion	Relatively fragile Deteriorates in sunlight Needs to be buried
High Density Polyethylene	Light weight Rapid installation Smooth finish Easily repaired Good impact resistance Easily bent Good corrosion resistance	Relatively high cost Requires specialised jointing techniques
Wood-stave	Smooth surface finish Can be cheap in some countries Can be built on site	Short life if inappropriate materials used
Glass Fibre Reinforced Plastic	Light Strong Corrosion resistant Smooth Low installation costs	Expensive Not widely available
Spun cast ductile iron	Very strong Long life Durable Smooth	Unlikely to be available locally Expensive Very difficult to repair Heavy to transport Difficult to make bends

[Adapted from: ITDG, 1987]

FIGURE 2.24: Comparison of penstock materials

a wider market.

2.7. STANDARDISATION

The standardisation of design, and rationalisation of design procedures, can result in substantial reductions in the cost of mini- and micro-hydropower equipment.

By standardising designs, manufacturing costs and delivery times can be reduced, design costs can be spread over a number of units, and ultimately reliability can be increased due to the reduction of design errors. This can improve the viability of hydropower equipment manufacture.

Crossflow turbines best lend themselves to standardisation. Their inherent characteristic of being able to elongate the runner to increase the capacity makes for few design changes between machines. In China approximately 80% of the component parts of Francis, Kaplan and propeller turbines are standard [UNIDO, 1983]. Here, in the region of 88,000 small and mini-hydropower stations have been built. In Thailand two sites with capacities of 1MW and one site of 2MW were installed with the identical turgo turbines, they had similar designs for the generators, and either the same or similar design for most of the other powerhouse equipment, even though each site had different head and capacities. This has allowed for a smaller stock of spare parts, common operation and common maintenance procedures, all resulting in cost savings. Although the design in each case was not optimal for the site conditions, overall the cost reductions have been considered to more than compensate for this [Chulapongs Chullakesa, 1991 (b)].

2.8. CHAPTER SUMMARY

There is wide scope for reducing the cost of hydropower equipment, particularly in the micro-hydropower range where there are possibilities of using cheaper construction methods than those used for larger equipment. Less costly production techniques can be used particularly for equipment with low capacity, where the forces upon the equipment are lower and when equipment efficiency is often not so important. This is seldom possible in the mini-hydropower range, and thus in some cases the cost per kW can actually rise with larger equipment. Manufacture of micro-hydropower turbines has been undertaken in many developing as well as industrialised countries, whereas considerably fewer have attempted to manufacture equipment for the mini-hydropower range. This is principally due to the increased difficulty in producing larger equipment, but also due to the increased importance of good efficiency characteristics required which have seldom

been achieved in developing countries other than China.

Crossflow turbines are the easiest turbines to manufacture, not requiring casting facilities, and designs being readily available. Their disadvantages are that they have a lower peak efficiency than other turbines used, and they are only used in the micro-hydropower range due to their poor mechanical strength. Reaction turbines are more difficult to manufacture than impulse turbines, and are more likely to suffer from cavitation. They have the advantages of higher peak efficiency, and can be directly coupled to a standard generator at low-head sites. In certain circumstances the use of off-the-shelf centrifugal pumps can be a cheaper option where efficiency and controllability can be sacrificed.

Synchronous generators are predominantly used at mini- and micro-hydropower schemes. However, induction generators are easier to construct, are more reliable than synchronous generators and are more able to withstand overspeed. They are used at some grid connected mini-hydropower sites, and are being developed as a viable option for isolated micro-hydropower schemes with capacities below 30kW, when used in conjunction with an IGC.

Flow control equipment is difficult to produce, requiring precision manufacture. Electronic Load Controllers are suitable for micro-hydropower sites where there is not a need for water conservation. Their manufacture requires the availability of electronic assembly facilities.

The most suitable material for penstock will depend upon local circumstances. This is also the case with drive mechanisms for micro-hydropower schemes.

CHAPTER THREE:

TECHNOLOGY TRANSFER AND INTERNATIONAL COOPERATION

3.1. INTRODUCTION

International cooperation has been seen to be a necessity for the advancement of the energy sector within a country, and indeed [Blakeney, 1989, pp.57]:

> "The assumption of almost all proponents of the transfer of technology is that such transfer is a prerequisite, even an imperative, for desirable economic and social development."

In South-East Asia, the transfer of technologies to communities is not new, having occurred for many centuries, however, until recently this process would have mostly taken place via diffusion between neighbouring communities, rather than technology transfer between nations. A description of the different methods of transferring technology presently employed will be discussed within this chapter, along with the factors affecting their success.

3.2. TECHNOLOGY TRANSFER

Technology

Technology has been defined in many different ways, encompassing both knowledge and products [ESCAP (a)]. A definition which is useful in the context of this thesis is taken from the World Intellectual Property Organisation's Licensing Guide for Developing Countries [WIPO, 1977, pp.28]:

> "Technology means systematic knowledge for the manufacture of a product, the application of a process or for the rendering of a service, whether that knowledge be reflected in an invention, an industrial design, a utility model, or a new plant variety, or in technical information or skills, or in the services and assistance provided by experts for the design, installation, operation or maintenance of an industrial plant or for the management of an industrial or commercial enterprise or its activities".

Thus, as well as the knowledge necessary to manufacture or operate, technology may also encompass management and financial know-how.

Technology Transfer

Technology transfer has also been defined in many ways according to the discipline within which it is being used [Zhao, 1992]. The transfer does not comprise the mere sale or lease of goods, and neither can much of technology be made explicit in manuals: rather it is a learning process, deemed to be successful when the skills required have been imparted to the receiver. A definition which best describes the process in the context of this thesis is [Cromwell, 1992, pp.979]:

> 'Technology transfer is the movement of technology between technical, economical and cultural environments, through a process of introduction, adaption and adoption.'

The skills, knowledge and capabilities imparted may lead to the recipients being capable of repair and maintenance; of modifying and adapting a product; or of designing and producing new equipment. Generally, technology transfer is limited to transfers between organisations from different countries, but the transfer can also take place within a country.

3.3. METHODS OF TRANSFERRING TECHNOLOGY

There are many methods of transferring technology, and no single method dominates. The more widely used methods are shown below in figure 3.1. This is followed by a brief description of the advantages and disadvantages of the most commonly used methods.

Joint venture agreements

One of the main advantages of a joint venture agreement is that the recipient company is likely to get ample support from the supplier, as the supplier is likely to be obtaining a proportion of the turnover and profits. A disadvantage of this form of contract to the recipient company is that the supplier may not consider it necessary to transfer all of the skills required for independent manufacture, as this may be seen as a duplication and a waste†.

---

† Only a short description of the different forms of agreement are given here. For further information the reader is referred to the following literature [ESCAP (a); Stewart, 1979].

	ACTIVE ROLE FOR SUPPLIERS	PASSIVE ROLE FOR SUPPLIERS
FORMAL AGREEMENTS	Joint venture Supply of turn-key facilities Licensing Direct foreign investment in a subsidiary Provision of consultants Training Merger, or acquisition Technical services Build-Own-Operate-Transfer, and similar contracts	Supply of machinery and plant Supply of patents Inspection tours of existing sites
INFORMAL ACQUISITION METHODS	Feedback from exporting Information from trade fairs	Copying of imports Information from technical manuals, journals and sales literature Reverse engineering Acquiring key staff

[Adapted from: Barrow, 1989]

FIGURE 3.1: Methods of transferring technology

Licensing agreements

Many licensing agreements only involve the assembly of component parts, which offers little in the way of technology transfer, as the capabilities to design and produce the equipment independently are not passed on. Also, the licenser has no tangible assets to protect and thus no incentive to provide support. One of the main advantages of this form of agreement to the recipients, is that they are likely to gain customers due to the existence of a market for the product under license. This method provides quick acquisition of a new technology and expertise.

Turn-key contracts

A turn-key project is such that the supplier is solely entrusted with a project's development, including agreements with sub-contractors, until the project is handed over to the purchaser, usually when the plant is fully ready to operate. Turn-key contracts can involve project design, engineering, procurement and manufacture of equipment, construction management, commissioning and training, and subsequent problem solving,

all of which are the responsibility of the supplier.

Often national electricity utilities in developing countries will prefer turn-key projects, as they are seen to be quick to implement, and as final payment need not be made until the project is fully operational, they can in general be trusted to work. Many utilities have become accustomed to buying from abroad, due either to habit or perceived improved quality and reliability of equipment, and this method is often preferred by financial agencies [UNIDO, 1985]. Pricing conditions for a turn-key project are usually fixed in the contract, such that any unforseen price increases are met by the supplier, and the completion date is also set.

A major limitation of this form of lump-sum contract is that it does not encourage the supplier to help the receiver make a profit [UNIDO, 1985], as the supplier company has no financial stake in the venture [UNIDO, 1977]. This packaging of large power projects also effectively excludes local companies from participation, as will be discussed in more detail in section 3.5.1. Although turn-key projects do normally work as requested in the project contract, it has been expressed by UNCTAD that [UNCTAD, 1989, pp.54]:

> "It is generally accepted that turn-key projects do not contribute to strengthening the technological capacity of recipient countries."

Build-Own-Operate-Transfer, and similar contracts

There are several related methods of transfer entitled, Build-Own-Operate-Transfer, Build-Operate-Transfer, Build-Own-Operate-Train-Transfer, and Build-Own-Operate, which are only briefly described here:

- Build-Own-Operate-Transfer (BOOT) - enables private businesses to build, own and operate plant, sometimes for up to decades, before transferring them to the national governments;

- Build-Operate-Transfer (BOT) - initial operation by the builder, and gradually transferred to the recipient organisation or government;

- Build-Own-Operate-Train-Transfer (BOOTT) - as with BOOT, but with an added training component;

- Build-Own-Operate (BOO) - here the plant will be privately owned.

The World Bank have endorsed BOOT methods [Goldsmith, 1992], and international financial support is becoming more readily available. One advantage of the BOOT contract to the recipient country is that the loans do not require state guarantees and they are paid off by the owners rather than the recipient country. Again, these methods do not by themselves transfer technology, as knowledge does not necessarily pass to the receiver.

Training

Training is a common factor of many formal transfers of technology, with training of local people at the managerial and technical levels becoming almost a standard requirement in technology transfer agreements [UNCTAD, 1992]. Whereas a scheme involving substantial training aspects may take longer to become operational than a turn-key project, working with and training the client reduces operational costs and thus overall costs. Unfortunately, in many cases suppliers have not been committed to providing adequate training, as a better profit can be gained from a company which is dependent upon the suppliers' services. Also most companies do not have adequate training expertise, particularly in cases where the trainees are from another culture.

There are many different forms of training, including on-the-job training, training abroad, study tours and seminars. In-country on-the-job training is often preferred as it provides the opportunity for the technology to be adapted to the local conditions.

Other methods

Much technology is transferred via informal methods where there are no financial agreements.

A common informal method of technology transfer is reverse engineering, often starting with the manufacture of spare parts, and leading to production of all component parts. Technology is frequently copied in this way, often breaking the law of intellectual property rights. This has been the case, for example, with Chinese manufacturers copying the design for the turgo turbine, as developed and patented by Gilkes, England.

EX BIBL. UNIV. EDINBURGEN.

Another popular method is whereby foreign consultants are employed under the condition that they will work along side nationals in order that the latter may pick up knowledge as they work. However, in many cases this fails to materialise due to the pressing time constraints placed upon the project [Huie, 1990]. In Malaysia, however, this method has been successfully utilised by one of the electricity corporations, whereby foreign consultants engaged in the design of a project are also required to help train local staff [Duder]. The first five mini-hydro projects implemented under the instigation of the corporation were turn-key contracts, with little transfer of technological know-how being obtained [LLN, 1988]. In the second phase, a large percentage of the funds were spent upon local materials and labour, with the result that all of the 16 schemes were constructed by local contractors [WPDC, 1987].

3.4. TECHNOLOGY TRANSFER FEES, THE LAW AND RESTRICTIVE PRACTICES IN FORMAL AGREEMENTS

3.4.1. Technology transfer fees

There are many ways in which a company can gain financially from the transfer of its technology to another country, as shown in figure 3.2.

	Explicit charges	**Hidden charges**
One-off payments	Technical know-how fees Sale of capital equipment	Over-pricing of goods and services
Long-term or continuous payments	Dividends Interest Royalties Management fees Maintenance and service	Dependency upon the supplier for spare parts The enforced purchase of services from the supplier

FIGURE 3.2: Repatriation of funds to the supplier of technology

Hidden charges are often enforced, as has been the case in Thailand, for example, where Thai companies have been required to purchase raw materials, intermediate products and machinery from the suppliers, although cheaper equipment has been available locally [Ng, 1986].

3.4.2. The law and guidelines affecting technology transfer

There are many laws relating to the protection of the supplier from disclosure of information. These include:

- copyright law, which, for example, protects a piece of written work, or computer software, but not the underlying concept of a design or process;

- patent law, which protects the use, sale and manufacture of a product, process or idea, for a given period.

Patents can be taken out either within particular countries, or internationally via the Patent Cooperation Treaty, however, few developing countries are signatory to this treaty and indeed none of the countries under study are signatories [Patent Office, 1986]. There is no such thing as a 'World Patent'. One of the main reasons why companies are reluctant to transfer technology is the possible loss of their ownership of the product patent, particularly within a country which does not enforce laws protecting patents. Under the terms of the General Agreement on Tariffs and Trade (GATT), developing countries have to incorporate provisions in their own law to protect these internationally recognised property rights. The GATT agreements aim to liberalise world trade by reducing trade barriers and other measures which distort competition, and stabilise tariffs. All member states are guaranteed the same import and export duties and charges from other member states, other than where regional trading agreements, and some special arrangements with developing countries are concerned. It will thus be more difficult for designs to be copied, and informal transfers of technology will become more difficult. Of the three countries under study, only Thailand is presently a signatory to GATT [GATT Information Service, 1991], however, it is anticipated that it will become increasing difficult for countries to trade effectively on the world markets and remain outside of the treaty.

At present the protection of the rights of the receiver rely upon the terms of the transfer contract. It is thus the responsibility of the receiver to make explicit conditions relating to documentation, technical assistance and training, and for the provision of skills to enable effective design, management, manufacture and market analysis.

The Group of 77 developing nations, the United Nations Conference on Trade and Development (UNCTAD), and the World Intellectual Property Organisation (WIPO) have been negotiating a Code of Conduct on the international transfer of technology, which

states unlawful practices and outlines responsibilities and obligations of the parties involved [Blakeney, 1989]. The Group of 77 developing nations has proposed that this code becomes universally and internationally binding, in which the transfer of technology is recognised as an important instrument of development [Kabir-Ur-Rahman Khan, 1988].

3.4.3. Restrictive transfer practices

Most technology transfer agreements involve restrictions imposed by the supplier upon such things as marketing territories, purchasing and pricing strategies, diffusion of the technology, and local research and development [Whitby, 1984]. A typical example of this is shown in the licensing agreement between a company in the United Kingdom and National Energy Administration of Thailand, for the assembly of Electronic Load Controllers (ELCs), which stipulated that: the equipment must not be sold outside Thailand without permission; the main circuit board must be purchased from the supplier in the United Kingdom; and the design and assembly must not be transferred within Thailand. Thus, although equipment is being assembled within the country, the country is restricted from developing the technological know-how needed to produce the equipment independently.

3.5. TECHNOLOGY PACKAGING AND DEPENDENCY

3.5.1. Packaged technology transfer

Packaged technology transfer contracts are where many separable agreements are included within one contract: for example, equipment supply, civil works development, technical assistance, training, management, financing, and marketing studies. Many large power supply projects are packaged in this way by funding agencies, effectively excluding local participation. Packaged deals offer better guarantee that deadlines will be met, and that performance is satisfactory [Djeflat, 1988], often resulting in a quick set-up time for a project. Turn-key, BOOT and similar contracts are forms of packaged technology transfers. Many electricity utilities appear to prefer this method of contracting, as they can relinquish their responsibility for the successful commissioning of a project. Also they are usually available with long-term financing, which can overcome the domestic financial restraints often experienced within developing countries. This bias against local companies can be overcome by establishing a financial service which enables a local purchase on terms comparable to that of the imported equipment, as has been initiated in the Philippines [NRECA, 1983]. Most developing countries have

a lack of foreign capital for imports and thus this facility can help promote locally manufactured products.

3.5.2. Unpackaging technology

It has been argued that packaged contracts perpetuate dependency upon foreign suppliers [Ng, 1986]. Unpackaging the technology allows individual aspects of the project to be given to different organisations, to suit the recipient's, rather than the supplier's, interests. The advantages to the recipient include:

- cheaper local equipment may be chosen;
- the recipient has greater input and control over the contract;
- the recipient is more likely to learn from the process through this greater involvement.

The disadvantages include the likelihood of a longer completion time, possibly higher costs, and the problems associated with ensuring compatibility between components from different suppliers.

3.5.3. Dependency

It is important that the type of technology being transferred is appropriate to local needs and does not give rise to a draining dependency for the recipient community. Suppliers usually look for follow-up sales of raw materials, component parts, additional products, technical assistance, and maintenance contracts, and thus the more dependent the recipient, the more likely these will be required [ESCAP (a)].

There is often a conflict between the quick acquisition of technology in the form of a turn-key project, and the longer process of learning of skills, which would ultimately lead to a greater degree of self-reliance.

3.5.4. The effects of aid

Foreign financial aid is often given as subsidised credit for equipment and services from the donor country, and it is generally believed that the donation of equipment will help to promote the diffusion of the technology. UNCTAD have described how this is not often

the case, due to the drain caused by the requirement for inputs from the recipient where there is often little capital available [UNCTAD, 1986]. Without a coordinated approach, many different types of equipment will be used, leading to increased difficulty in the supply of spare parts, training and maintenance, and creating a dependency upon the suppliers.

It appears that many NGOs and other international organisations are mainly concerned with setting up pilot projects. This has particularly been the case in the Lao PDR in projects where the one-off nature of the scheme has provided a distorted view of the costs involved, and their experimental nature has proved to be a burden upon some of the user communities. They are often heavily subsidised by either the host or foreign governments, and do not show the true cost of the scheme. Indeed the cost is often considerably higher than would be achieved for a full, in-country development. Single projects implemented by NGOs and government agencies seldom enhance the prospects of concerted nation-wide programmes, and rarely increase the knowledge base in the country. The donation of equipment also undermines local industry's attempts to sell and produce equipment within the country, as locally made equipment is not bought where foreign equipment is free or accompanied by long term payment deals preferred by funding organisations. In some cases import taxes for aid equipment are reduced, thus making it more difficult for local companies to compete [Huq, 1993].

In cases where aid has been given to develop local industrial capacity, the aid has often led to creation of overcapacity, leading to high unit cost of production [Huq, 1993]. Again, this shows the importance of proper analysis of the market and conditions within the country before investment is made.

3.6. THE PARTIES INVOLVED WITH TECHNOLOGY TRANSFER

The main participants in the transfer of manufacturing technology - the supplier firm, recipient firm, supplier country, and recipient country - each have different motives and sometimes a conflict of interests [ESCAP (a)]. Figure 3.3 shows some of the expectations of each of these parties involved in a technology transfer contract.

3.6.1. The recipient company and country

The advantages of local manufacture of equipment are numerous, ranging from the reduction in foreign exchange requirements, to the increased body of locally available knowledge and expertise, which thus becomes easily accessible. Designs and fabrication

Aspects	Recipient company	Recipient country	Supplier company and supplier country
Technology	Adaptable without much research and development	Adaptable with the available infrastructural support Replicable by other companies	Technology which is being phased out
Mode of acquisition	Packaged turn-key contract	Unpackaged contract	Packaged turn-key contract
Maintenance of spare parts	Least maintenance costs/problems	Least maintenance costs/problems Assurred supply of spare parts on a long term basis	Maintenance would require supplier's service Spares supplied as part of the contract for a limited period
Manpower training	Installation, operation, and maintenance skills	Installation, operation and maintenance skills	Operation and routine maintenance
Market	Assured market expected	Export market hoped for	Concerned with internal market, restrictions on export market
Life cycle	Long life cycle	Long life cycle	Supply of product having frequently changing models
Patents and other restrictions	No restrictions on replication, diffusion, or market Maximum use of local talents, and indigenous machinery	No restrictions upon diffusion, or export market Maximum use of local talents, and indigenous machinery	Restrictions on replication, diffusion and market Minimum, or little use of local talents

[Source: ESCAP (b)]

FIGURE 3.3: Expectations of the different parties to technology transfer

techniques can be adapted to local conditions and the skills which develop remain available to maintain and repair equipment. Also the skills and know-how gained by one industry will often be of benefit to others within the area. The local manufacture of hydropower components will facilitate easy repair as well as enabling designs to be more easily adopted to local requirements. If local capabilities are not built up then the communications gap which exists when spare parts are needed, or technical problems in operation must be solved, can lead to the insustainability of the imported technology. Local manufacture and participation reduces the foreign component of the costs, making a scheme more attractive in the eyes of the host government.

The benefits to the receiver of technology transfer are numerous, as can be seen from figure 3.4. The company is able to acquire know-how without the need to risk the investment of time and money in research and development.

The introduction of technology to a country will inevitably have an impact upon indigenous industry, raw materials, energy supply, the environment, and employment. It is important that the transfer of technology should not strangle local initiative, preventing

investment by local companies, due to the often subsidised competition from abroad.

	Impact upon recipient company	Impact upon recipient country	Impact upon supplier country	Impact upon supplier company
Advantages	Acquisition of new products Increased profits Larger market share Growth Acquisition of new processes and methods	Industrialisation Increased prospects for exportation	Increased revenues Impact upon economy Impact upon international position	Profit Market Scale economies
Disadvantages	Dependence	Dependence	Possible loss of jobs and exports	Likely loss of control

FIGURE 3.4: Impact of technology transfer upon the different actors

Receiver preparation for technology transfer

The main source of new, industrial technology is from industrialised countries, there still being relatively few South-South exchanges. Sources of a technology are found via many ways, including: informal contacts; trade fairs; publications; consultants; international organisations; government information services; or competitive tendering. Evaluation of the different suppliers of the technology is often difficult for small companies, and government information services are often in a better position to do this. In choosing a foreign partner it is important to consider their competence, both in terms of their mastery of the technology and their experience with international technology transfer. Other factors such as the status of the technology, its cost, and the partner's willingness to transfer know-how and train managers, are also important [ESCAP (a)]. The method of transferring technology is dependent upon the recipient's technological preparedness in terms of the skill base of the labour force and management.

Before deciding to request the transfer of a technology it is important for the recipient company to assess such things as: local manufacturing capabilities; human resources; training requirements; market size; export possibilities; manufacturing costs; the impact upon balance of payments; employment opportunities; environmental effects; and resources. The resource base already available is one of the main factors influencing the type of technology transfer and the likelihood of its success. For example, the type and size of existing machinery, the availability of the skills needed to operate it, and the nature of local supporting industries, will all be important. For the receiver of a technology to be prepared in order to absorb the technology, it is essential that a substantial degree of self analysis and planning be undertaken.

The role of the recipient country's government

In general, governments want to save foreign currency by import substitution, create jobs, use local materials, broaden the industrial base and improve labour skills [ESCAP (a)]. They are often also eager to discourage the importation of technology which is already available within the country. Whereas it is generally private companies which are the main importers of technology and not the governments, recipient governments have an important role to play in creating an atmosphere which will attract foreign investment, and enable the absorption of technology once this investment is being made. They are responsible for enabling the formation of a well-trained population which is numerate, literate, and has technical and professional skills beneficial to the absorption and diffusion of technology within a country, as well as establishing the necessary infrastructure to support it. They are also able to affect currency valuation, tariff policies, import duties, business and other taxes, and government stability, all of which may affect investment. In relation to specific policies they are in a position to enact laws related to investment, such as investment incentives, direct government investment, tax exemption, and reduced tariffs on machinery. In order to protect an infant industry, import restrictions and favourable tariff policies may be applied though these may reduce competition and artificially increase prices.

A country can only be said to have a technology once diffusion of the technology has taken place within the country [ESCAP (a)]. It is possible that whereas one company within a country can acquire a technology, this does not necessarily mean that the country has the technological capabilities, as, for example, if the company is a subsidary of a foreign company then this technology can quickly disappear.

As has been described above, many small companies can not sufficiently evaluate rival foreign technologies, and government agencies have been set up in several countries to provide a service to small companies. Also, in some cases a government may contribute to negotiations and is sometimes a signatory to a technology transfer agreement.

3.6.2. The supplier company and country

Disadvantages to the supplier

For the supplier, technology transfer usually implies a partial loss of ownership, the increased possibility that the technology may become public knowledge, and the creation

of a competitor which has lower production costs (as shown in figure 3.5). At the end of any royalty period the supplier has no income from the recipient, and if the supplier is not able to create an improved change to the technology, the only way to compete may be to reduce its own costs. With joint venture agreements the supplier also needs to be aware that the quality of the products made by the recipient may not be of the standard of those produced by themselves, and could damage the supplier's name. Thus companies are generally reluctant to transfer technology to other organisations, unless there are profitable reasons for doing so (as described below).

The technology needed to manufacture micro-hydropower equipment and to implement micro-hydropower schemes is, however, available from several NGOs. Unfortunately the technology which these NGOs have at their disposal is seldom of the quality available to the major manufacturing companies. It is, however, often suited to the local manufacturing capabilities available in many developing countries and suitable to their needs for low cost and easy to produce equipment. Such support from NGOs is seldom available in the mini-hydropower range.

	Positive effects	**Negative effects**
Short-term impacts	Profit from sale of technology Profit from sale of equipment	Loss of export markets Emergence of new competition Jobs not created within home country
Medium and long-term impacts	Opening of new markets with growing demand Availability of cheaper products	Where new competitive conditions are not created, the supplier risks its place in the market.

FIGURE 3.5: Impact of technology transfer upon the supplier

Advantages to the supplier

As well as the financial gain from the transfer, the supplier of a technology is also able to gain from [ESCAP (a)]:

- the possibility of improved, or new products due to the receiver's local knowledge of the local working environment;

- the creation of goodwill;
- accompanying advertisement of the company, and an enhanced international image;
- possible export benefits, as equipment being exported from certain developing countries benefit from reduced tariff access to the United States of America and the European Community via the Generalised System of Preferences (GSP);
- easier access to a market which may be protected, as many developing countries impose a high tariff on manufactured goods unless there is a large local component;
- lower labour and production costs, in situations where the supplier transfers its manufacturing base to a developing country.

In the case of joint ventures, local partners enable good communications with the customers, public and bureaucracy within the country. They are able to arrange transport, deal with officials, gain an advantage at the tender stage of certain contracts, and often purchase materials and labour more cheaply than a foreign company.

Criteria looked for by the supplier

In deciding into which country and company to invest, a supplier will often look for evidence of the following [ESCAP (a)]:

- political stability;
- good labour relations;
- a skilled workforce capable of absorbing the technology;
- economic stability;
- a sound banking and tax structure;
- good local and region infrastructure;
- tax exemptions;

- a strong home market;
- adequacy of the law protecting the intellectual property rights of the supplier;
- simple procedures for foreign investment.

Research into the degree of importance placed upon these factors by European companies which are considering making investments in Thailand has shown that such companies consider the most important factors to be [Tang, 1982]:

- the presence of a growing market for the products manufactured;
- good labour relations;
- exemption from income tax.

Again the existing resource base will be of great interest to the supplier, as, for example, it will be easier to transfer the technological capabilities needed to produce turbines if the recipient company has already produced similar sized pumps.

3.7. TECHNOLOGY TRANSFER NEEDS WITH RESPECT TO MINI- AND MICRO-HYDROPOWER

There are many groups of recipients which need to be considered for the successful transfer of mini- and micro-hydropower technology. Each group will require different inputs and different methods of transferring the technology. Those important to this thesis include:

- technology transfer to manufacturers, enabling equipment design and manufacture;
- technology transfer to implementing organisations, enabling surveying and feasibility assessment, scheme design and scheme construction, as well as successful programme implementation;
- technology transfer which enables local electricity supply corporations to design and implement sustainable electricity supplies;

- technology transfer to the technology users, to enable operation and maintenance by those users, and possibly construction;

- technology transfer to training institutes, to widen the knowledge-base with respect to the technology;

- transfer of the knowledge concerning the end-uses of the electricity to the recipients within a community.

It has been well documented that the participation of local communities in small hydropower projects produces many benefits [Inversin, 1986]. Local communities need the skills to operate and perform minor repairs, such as the changing of fuses, resetting of trips, cleaning of the trash rack, and also to check voltage and frequency settings of the generator [Inversin, 1986]. Transferring the skills necessary to aid in the construction, operation, maintenance and repair of a hydropower scheme will enable the scheme to be less dependent upon external sources and thus it may be more sustainable. Many of the skills required in the construction of a site will already be possessed by local communities. For example, the capital costs of a scheme may be reduced by constructing the powerhouse using local labour and materials.

It has been shown that by training local representatives in the importance of maintenance upon the reliability of a supply, as well as in the basic principles of operation, schemes can be made more sustainable [Lepiten, 1990]. At a 1MW scheme in Thailand, for example, outage of a scheme will result in a loss of revenue of US$4,800 per month [WPDC, 1991 (b)], and thus training in maintenance and repair can provide direct financial returns. One effective way of achieving adequate training is by allowing future operators to participate in the construction of the scheme [Hislop, 1987]. This enables a thorough understanding of the whole scheme to be gained, as well as often promoting an attitude of commitment to the successful running of the scheme.

The process of transferring the technology needed to manufacture hydropower equipment includes: training people in the skills necessary to produce specific equipment; training people to use new machinery; and training managers to schedule the production such that manufacture can take place quickly and smoothly. This is often best undertaken in the workshop of the recipient organisation, as the facilities and environment may be significantly different to those in the supplier's workshop, for example.

To transfer to a national organisation the capabilities to plan, design and implement small-scale hydropower schemes is a task requiring long-term commitment. In Thailand this is being undertaken by having staff work alongside foreign experts during several scheme developments, with an increasing proportion of the work being passed to the recipients, so that the skills are gradually transferred. This has been done in conjunction with key personnel being taken to see how similar tasks are being performed in the supplier's own offices abroad. This is considered to have been a success, with much of the third scheme developed having been designed and implemented by Thai staff [pc: Chulapongs Chullakesa]. It is, however, important that implementing organisations and national energy organisations are aware of the range of technologies available, and the associated advantages and disadvantages, however, this is seldom achieved when only one company is employed to transfer their technological capabilities.

3.8. FACTORS AFFECTING TECHNOLOGY TRANSFER

Some of the basic principles which will aid technology transfer include [UNIDO, 1977]:

- the technology should be appropriate to the local conditions;
- the supplier should be competent at providing the required training;
- licensed technology should utilise local resources, including materials, skills, and management as much as possible.

For a transfer to be successfully achieved requires the supplier to have a thorough understanding of both the technology, and the capabilities of and facilities available to the recipient. Technology designed for certain social conditions and technical environments may not fit into a new situation, and thus it may not be possible to transfer a technology directly. As has been shown in section 2.1 (particularly figure 2.4), this is often the case with respect to the designs for small-scale hydropower equipment.

In developing countries, technologies which are appropriate to the local conditions are usually labour intensive, relatively cheap to produce, and economic in terms of financial exchange. Western suppliers, however, are often being charged on the one hand with providing obsolete technology, being passed off as appropriate, and on the other with providing inappropriate, capital intensive technology. Western companies have developed few new technologies which are labour intensive, and thus the technologies which they are able to supply are not always appropriate to the conditions of developing

countries.

Most turbine equipment manufacturers are in urban areas, where there is a larger skilled workforce and easier access to financial and infrastructural support than is the case in most rural areas. Most users of mini- and micro-hydropower equipment, however, live in rural areas, and thus rural workshops are often better placed to support micro-hydropower developments. However, there is a balance to be made between the capabilities of the rural workshop and the requirement for efficient and reliable equipment, as it is often difficult to assure good quality equipment from rural workshops.

Failures of technology transfer

A transfer can fail for many reasons including [ESCAP (a)]:

- inappropriateness of the technology;
- failure of the contract;
- inadequacy of the existing resource base;
- failure of recognising the capabilities of the workforce and management;
- poor selection of experts;
- failure to take full advantage of an expert's skill;
- underdevelopment of supporting industries.

Technology often fails to be transferred effectively even though the recipient has paid for it. In many cases the supplier blames the recipient for its inadequacies in absorbing the technology, and seldom is it insisted upon by the recipient that the technology is fully absorbed. For a complete acquisition of the technology, the receiver must ultimately know everything about the production process essential for the product's manufacture, and must have the skills to perform all the tasks required. If the recipient is not able to continue to produce once the supplier has withdrawn its support, then it is apparent that only the rental of production techniques and not absorption of them has taken place. If the technology is not absorbed then the country will be dependent upon further licensing and technology imports.

Technology transfer to research organisations is rarely an effective way of establishing a technology within a country due to poor linkages between research organisations and industry. Successful transfers of manufacturing capabilities have occurred mainly where companies are predominantly locally owned [UNCTC, 1987].

It is widely recognised that small-scale hydropower schemes run by large generating authorities suffer many disadvantages such as [Hislop, 1987]:

- staff are reluctant to work on small-scale schemes in isolated areas;
- large bureaucracies increase the costs and delays associated with repairs;
- systems are often managed in the same way as large schemes and are thus uneconomical;
- conventional technologies are often used, even though they have high capital costs;
- the schemes are often dependent on external financing, as well as imported equipment and skills.

In the Philippines it has been recognised that decentralisation of rural electrification schemes is likely to be more sustainable than nationally managed schemes [Denton, 1979]. Thus there is a need for in-country technology transfer to individual village committees in charge of operation and maintenance of the schemes, and to local workshops to facilitate repair.

3.8.1. Nepal: An example of the successful transfer of micro-hydropower technology

The years since the early 1970's have seen the development of a thriving and locally sustainable micro-hydropower industry in Nepal. From the manufacture of equipment, to the promotion and development of sites, the Nepalese organisations have absorbed and adapted the technology to suit their local conditions. The success has been aided by the continued support from international NGOs and other agencies, which have provided training and advice, and also from both Nepalese and international financial and development institutions [Cromwell, 1992]. The process of technology transfer was of adaption rather than passive acceptance, with existing workshops rather than new workshops becoming involved in production, with small companies proving to be the best at receiving the technology [Chapallaz, 1992]. Some trainees of the initial workshops

have set up their own, and there are now several workshops producing micro-hydropower equipment, and the infrastructure now survives without outside inputs.

The success has relied upon [Cromwell, 1992]:

- these private sector initiatives;
- a favourable policy environment whereby schemes below 100kW were licensed and could be privately owned;
- existing demand for a less arduous method of rice milling and aspirations for electricity;
- the provision of initially small and increasing inputs from international and local organisations until the technology was firmly established;
- the effective targeting of public sector credit;
- the initial partnership with existing entrepreneurs.

3.9. INTERNATIONAL AGENCIES AND INTERNATIONAL COOPERATION

International cooperation has been of great importance in the dissemination of information about renewable energy technologies. It has involved cooperation at the world, regional, bilateral and in-country level, by both NGOs and intergovernmental organisations.

Due to the common problems faced by developing countries, there is the potential for both common information systems, and joint manufacturing initiatives. The main barriers to the establishment of these forms of cooperation are insufficient institutional framework and incompatible standards [UNIDO, 1985]. This is where international organisations are able to provide assistance. They are better able to organise regional expositions, training, and information services.

The role which international agencies can best play includes being able to:

- find partners for companies wanting to produce a new product;

- assist in the drafting of transfer contracts and negotiations;
- assess the technological needs of both a company and a country;
- organise international symposia to help the dissemination of technological information.

International organisations which are concerned with the transfer of technology in South-East Asia include†:

- Asian and Pacific Centre for the Transfer of Technology - established by the United Nations, they offer a technical information service on patents and trade secrets, and help clients to evaluate sources of technology and formulate contracts;
- German Appropriate Technology Exchange - concerned with the promotion of appropriate technologies within developing countries;
- Economic and Social Commission for Asia and the Pacific - entrusted by the United Nations to develop cooperation between countries of the Asia-Pacific region;
- United Nations Development Programme.

Cooperation in the manufacture and development of mini- and micro-hydropower schemes on the regional level can lead to the expansion of markets and thus better terms of investment due to economies of scale. Unfortunately rivalry and distrust between members of the Association of South-East Asian Nations (ASEAN), of which Thailand is a member, has been preventing real cooperation [Ng, 1986], and virtually no technology transfer has taken place between countries of South-East Asia [ESCAP (b)]. However, there have been several ASEAN cooperation projects on Science and Technology including: the establishment of a regional electric power information centre in Thailand; and the establishment of a mini-hydropower information exchange, with Indonesia as the focal point, which has as its objectives to identify and exchange information concerning mini-hydropower with the region. Also, outside the ASEAN, but within South-East Asia, there has been cooperation between Thailand and the Lao PDR over the development of large hydropower schemes and the sale of electricity between the two countries.

---

† Addresses of these and other organisations are given in appendix E.

3.10. CHAPTER SUMMARY

Technology transfer can be considered to be successful when absorption and diffusion of the technology by the recipient company and recipient country respectively has taken place such that the transferred project is fully operating without outside assistance. In order for the recipient of the technology to gain greater control over a technology transfer project, it is usually in the interest of the recipient to unpackage the contract. For absorption of a technology to be achieved it is most important that the technology transferred is suited to the existing available resource base.

Many organisations are involved in the diffusion and development of hydropower technology within a country, from the manufacturers of the equipment, to the scheme designers, and to the users and operators. All require the correct knowledge to work with the technology and thus all can benefit from appropriate training. Of the many different forms of technology transfer where absorption of the technology occurs, training is a major factor in all of them.

Each of the many parties to a transfer of technology agreement have different objectives. Although there are internationally recognised laws aimed at protecting the supplier of a technology, it is only the transfer contract which provides protection to the recipient.

Aid in the form of donations of hydropower equipment is not always beneficial, as it can undermine attempts by local companies to manufacture the equipment and become more self-reliant. Dependency upon foreign suppliers for spare parts, or technical assistance, is often a great burden upon the recipient's resources.

CHAPTER FOUR:
COUNTRY STUDY - VIETNAM

This chapter discusses the local manufacturing capabilities of companies producing small-scale hydropower equipment in Vietnam. This is presented in the context of their role in the present energy scenario in which the country finds itself, and the on-going electrification of its rural areas.

4.1. COUNTRY PROFILE

The Socialist Republic of Vietnam, with a surface area of 331,689 square kilometres, stretches over 1,630 km from its northern border with China to its southernmost tip. A relief map of the country is shown in figure 4.1. According to the 1989 census, 80.2% of the country's 64.4 million inhabitants live in rural areas†, with there being an average of five to six people per rural household [Nguyen Van Hanh, 1992]. The Mekong River delta and the Red River delta are homes to 24.3% and 22.1% of the population respectively.

The country is considered to be one of the poorest in the world, with a per capita Gross Domestic Product of approximately US$200 [Nguyen Van Hanh, 1992]. Although fifty years ago, income levels were broadly similar to those in Thailand, today they are approximately one-fifth of Thailand's. This has been partly due to the rapid developments which have taken place in Thailand, but also to the experience of war and ensuing isolation to which Vietnam has been subjected. Until 1994, the United States of America enforced an embargo against the country and vetoed all World Bank loans since the country's reunification. The lifting of this embargo promises to enable the provision of much needed finance and increased trade.

Economic development has followed two major phases: firstly, after reunification in 1975, until 1985, the country operated under a centralised system with a subsidised economy [UN, 1992 (a)]. Secondly, since 1986, many bold reforms, known as "doi-moi", or "renovation", have taken place aimed at rejuvenating its economic system, and establishing a free market economy. The Foreign Investment Law in Vietnam has supported these reforms by encouraging high-technology industries using skilled labour, service industries that earn foreign exchange, and the production of exports and import

† Rural areas are defined as those outside the capital, provincial urban areas, district chief towns and municipalities.

substitutes [IMF, 1989].

The country has historically had strong economic links with Russia and the old Eastern Bloc countries, but the collapse of the Soviet Union, its main trading partner and provider of a large proportion of the country's aid, has created a situation whereby Vietnam is now developing closer ties with its neighbours in Asia. It is presently pursuing its interest in joining the Association of South-east Asian Nations (ASEAN). Between 1990 and 1991 the country's exports to capitalist countries rose by 73% whilst its imports doubled [Hiebert, 1992 (c)].

The economic situation in the country is characterised by low levels of both savings and investment. Inflation, which was at 400% during 1988 was down to 18.6% for the twelve months ending March 1990, and has since remained at a low level. In 1991 Vietnam had a hard-currency deficit of approximately US$700 million, and a hard-currency debt of US$3.7 billion [Hiebert, 1992 (c)], whilst in 1989 there was a net resource transfer from Vietnam to the West [World Bank, 1990]. Exporters particularly are being affected by the country's shortage of working capital.

The International Monetary Fund (IMF) states of Vietnam that [IMF, 1989, p19]:

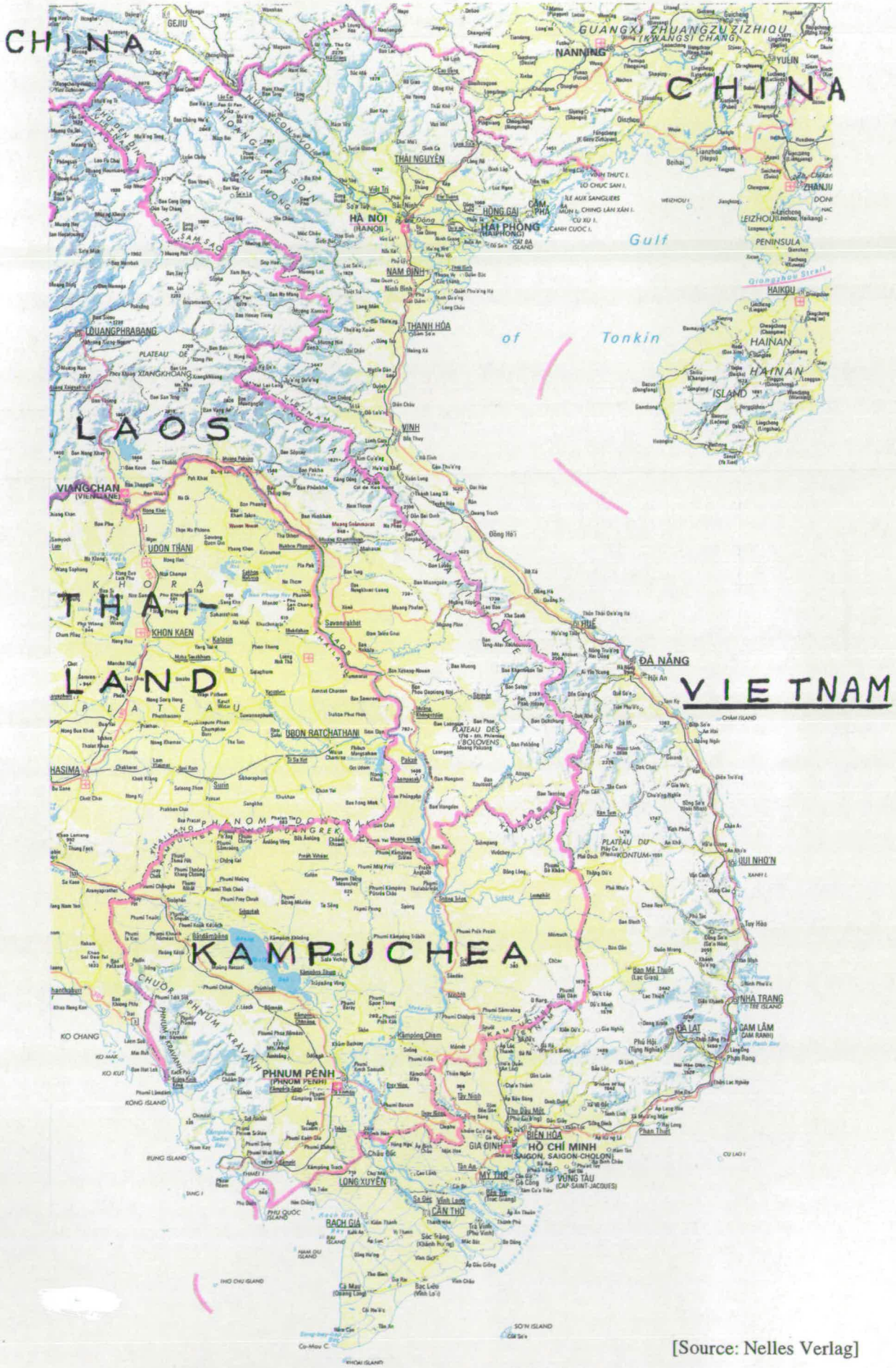
> "The industrial sector has been increasingly constrained by the chronic shortages of agro-based raw materials, the reduced availability of spare parts and imported inputs, power failures, efficiency and capacity utilisation problems, and Vietnam's poor transportation facilities."

Even with this in mind, due to the industrious nature of the country's people and the large extent of the natural resources present in the country, many people believe that Vietnam will become the next Asian "tiger" [Mallet, 1992], following in the footsteps of Taiwan, South Korea, Singapore, and Hong Kong. Firstly, however, the country has to overcome the problems of poor infra-structure, a restraining bureaucracy and an acute energy supply crisis.

4.2. ENERGY SITUATION

4.2.1. Energy supply and demand

Vietnam is very rich in indigenous sources of energy, including excellent quality deposits of anthracite coal [World Bank, 1990], extensive oil fields and large hydropower resources. Until 1989 Vietnam was a net energy importing country, but mainly due to its



[Source: Nelles Verlag]

FIGURE 4.1: Relief map of Vietnam

crude oil exports, it is now a net exporter [UN, 1992 (a)]. Presently coal and hydropower form the cornerstone of the national energy balance [UN, 1992 (a)].

In recent years approximately 20% of the country's national public investment has been spent on the energy sector, however, there still remains a huge supply/demand gap [World Bank, 1990], particularly in the electricity sector which is resulting in the need for load shedding and consumption rationing. Foreign investment is being sought in order to develop a coherent energy strategy, but until recently this has been hindered by the US embargo of the country, which inhibited the ability of Vietnam from obtaining World Bank loans [Vietnam Investment Review, 1992]. The Vietnamese government is seeking over US$4 billion of investment by the year 2000 to meet its rapidly growing energy needs [WPDC, 1994].

Energy consumption levels are considered to be one of the lowest in the world [UNDP, 1990]. If this level is to increase, which it will do if living standards improve, then the commercial energy pricing policy will be an important factor. At present, coal prices and domestic electricity prices are lower than their real costs, whereas the cost of oil products have recently merged with the market prices [UN, 1992 (a)]. The ability of the country's transportation infrastructure to deliver this energy to consumers is considered to be one of the major restraining influences which may emerge to constrain economic growth [World Bank, 1990].

It is important to realise that commercial energy supplies are only a small percentage of the country's total energy consumption, whereas biomass supplies approximately 74% [FAO, 1991]. This is compounding the problems of deforestation in some regions, with less than 9% of the country presently under forest, where as in 1945 the level of forestation was approximately 44% [Nguyen Duc Loc, 1991]. Wood and charcoal are important sources of energy for both the rural and urban population [UNDP, 1990], and therefore several strategies are being implemented in order to limit the impact of wood usage on the remaining forest. Perhaps the most important of these is the improvement in the efficiency of cooking stoves, and attempts have also been made to promote the use of coal for cooking and encouraging the planting of fuelwood. In rural areas, limited investment has also been made into promoting micro-hydropower for mountainous areas and the use of biogas for low lying regions [UN, 1992 (a)].

Energy usage is different in the rural and urban settings, with urban energy usage being mainly for industry, cooking, lighting, air-conditioning and other electric appliances, where as in rural areas the predominant uses of energy are for cooking, lighting, family

food-processing, family handicraft, and pumping for irrigation. In rural areas there is a greater reliance upon non-commercial energy sources, and communities are generally self-sufficient in obtaining their energy resources from their local environment [UN, 1992 (a)].

Renewable energy equipment

As well as the use of micro-hydropower units which will be discussed in section 4.4, other forms of localised renewable energy schemes have been initiated. The most successful of these has been the development of biogas digesters, of which around 2,000 have been installed, with capacities ranging from 2 to 250 cubic metres [Nguyen Duc Loc, 1991], with the fuel being used for cooking and sometimes lighting. Only in one case is the gas being used to produce electricity [pc: Nguyen Duc Loc (b)]†.

Conditions are not particularly favourable for the use of wind turbines, with average wind velocities of only 3m/s to 4m/s along the 3,000km coast, and 2.5m/s to 3m/s on the plains, and central and northern regions of the country are prone to typhoons through the monsoon season. However, there are around 200 wind-driven mechanical pumps [Nguyen Thuong, 1990], and several hundred electrical wind generators of 100W and 500W peak rated capacity have been sold [Nguyen Duc Loc, 1991].

With a solar energy intensity of 70 to 122 kWh/m^2/year [Nguyen Duc Loc, 1991] and the number of sunshine hours in the North being between 1,400 and 1,800/year, and that in the South being 2,500 and 2,800/year [UN, 1992 (a)], Vietnam is in a good position to use solar power equipment. So far very few schemes have been initiated, however drying of agricultural produce relies upon the sun.

Subsidies have been made available by the government to promote some renewable energy technologies in Vietnam, although the shortage of government funds limits the extent of these subsidies. Demonstration projects have benefited from an initial 25% subsidy from local government, and a further 25% from central government [Nguyen Duc Loc, 1991]. These subsidies have been gradually reduced as the equipment costs have reduced and quality increased as the product becomes mature. Success has been achieved with a policy of establishing demonstration projects whereby the recipient would only

† The references to personal communications with Nguyen Duc Loc are numerous throughout this chapter due to him being both expert and translator for other experts for many of the author's interviews and technical visits. See the bibliography for details of the other experts who provided information during these interviews.

pay if the equipment worked satisfactorily. This has been followed by promotion of the equipment in the locality and post-sale service such as repair and maintenance [pc: Nguyen Duc Loc (b)]. This has had best results in the promotion of biogas digesters, whereby following the transfer of technology to groups of private individuals via training courses, approximately two-thirds of the 550 schemes set up in the southern province of Dong Nai were installed by private workers [Nguyen Duc Loc, 1991].

Commercial fuel costs

The cost of diesel is approximately 2,750 Dong/litre (US$0.25/litre) throughout the country, whereas kerosene, which is popular for lighting in rural areas, costs approximately 2,500 Dong/litre (US$0.23), or more in rural areas, and a kerosene lamp costs up to 6,000 Dong (US$0.56) [pc: Nguyen Duc Loc (b)]. A family on average might use approximately 4 litres of kerosene per month.

Electric lighting, both from the use of batteries and directly from a supply is becoming more popular. Batteries are used particularly in the plains areas and near to major roads, where diesel sets are to be found. A Vietnamese-made 60 amp-hour battery costs as low as 100,000 Dong (US$9.26), however the life expectancy of the Vietnamese-made batteries is only between a half and one and a half years [pc: Nguyen Duc Loc (c)]. To charge a 60 amp-hour, 12V battery would cost between 2,000 and 3,000 Dong (US$0.19 and US$0.28) per charge [pc: Nguyen Duc Loc (b)]. At best, this is equivalent to US$0.33/kWh, which indicates the priority people have for electricity.

In urban areas, the cheapest method of cooking is to use fuel bricks made from coal dust, mixed with saw dust [pc: Nguyen Duc Loc (c)]. A stove designed to use these fuel bricks can be bought for less than 5,000 Dong (US$0.46) in Hanoi. It should be noted here that the average wage in the towns is approximately 100,000 Dong (US$9.26) per month, and a University lecturer's wage in Hanoi is between 150,000 Dong (US$13.90) and 200,000 Dong (US$18.50) per month [pc: Nguyen Duc Loc (b)], though these are usually supplemented by income from an additional job. The typical annual income for a Vietnamese farmer is between US$150 and US$200. In the rural areas fuel wood is the most popular form of cooking fuel. This is often free, but in parts of Bac Thai province for example, fuel wood costs average 25,000 Dong (US$2.32) per cubic metre [Cromwell, 1991], and it has been estimated that a family of six in mountainous areas, where fuel wood is scarce, may spend 30,000 Dong (US$2.78) per month on fuel wood [pc: Nguyen Duc Loc (b)].

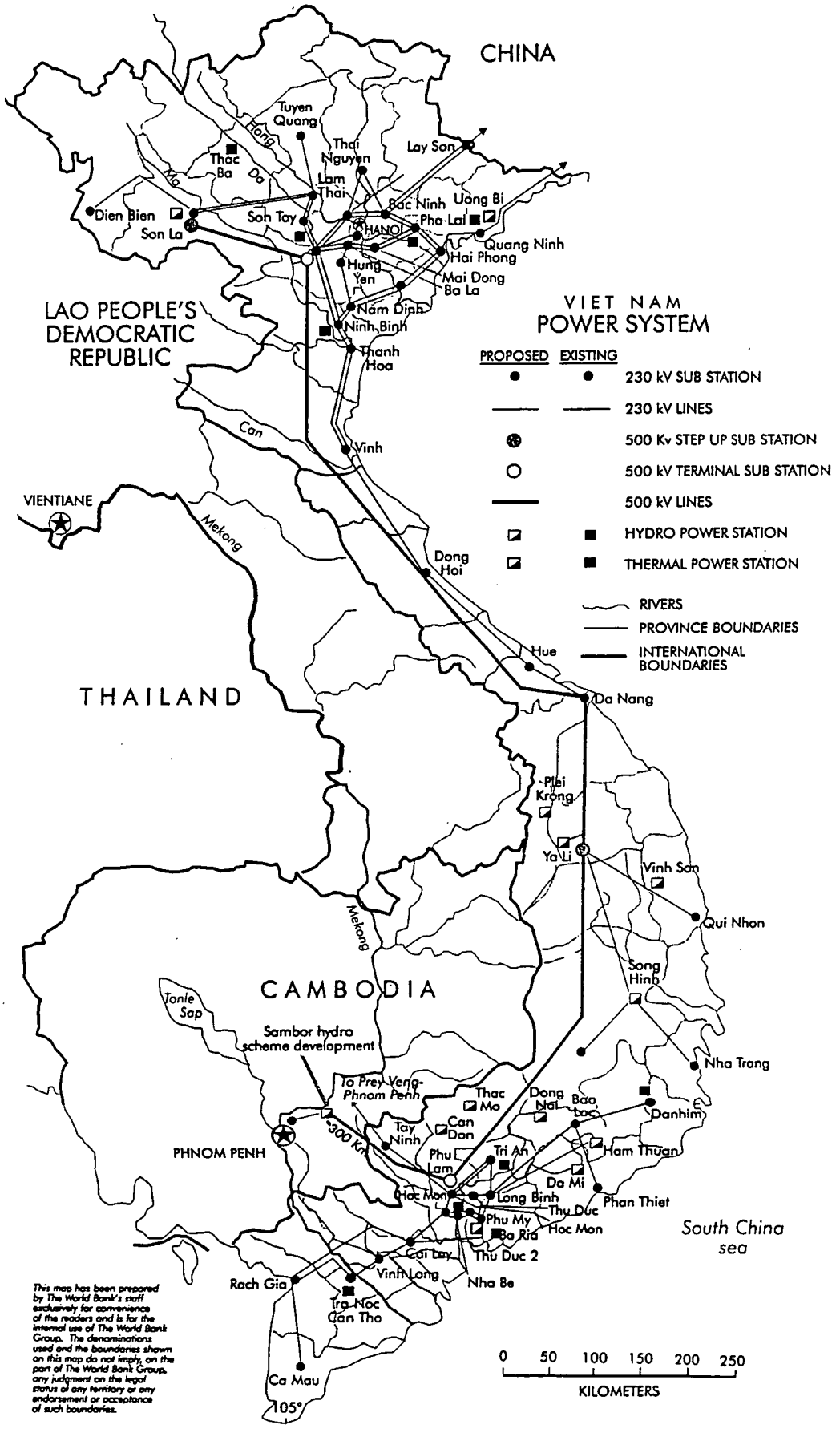
4.2.2. Electricity supply and demand

Vietnam presently has one of the lowest per capita electricity consumption rates in the world at around 47kWh/person/year [Nguyen Van Hanh, 1992]. Up until 1965, several medium-size power plants, and approximately 30 mini- and micro-hydropower schemes had been put into operation, but during the war from 1965 to 1975, many of these sites were at least partly destroyed [Nguyen Van Hanh, 1992]. This period had an immense influence in preventing the development of electricity production facilities in the country, and it was not until the period between 1975 to 1985 that networks of large plant were established. These included the Phalai 440MW thermal plant, and the Hoa Binh 1,920MW and Tri Anh 400MW hydro sites, amongst others. Figure 4.2 shows the sites of the larger stations and the extent of the 220kV grid system.

The shortage of power is acute throughout the country, especially in the South, where in the summer of 1992 there were up to four days per week where no power was available in Ho Chi Minh City. During this time industrial output fell by up to 30% [Asian Energy News, 1991]. This seasonal fluctuation has been due to the fact that between 70% and 80% of the electricity generated is from hydropower [pc: Nguyen Duc Loc (c)], with up to 80% of annual runoff being during the six month rainy season [World Bank, 1990]. These shortages have also been caused in part by the increase in demand, due to the increase in industrial production following the free-market reforms, and the expansion of the rural electrification network. The situation is compounded by power losses of around 20% [Asian Energy News, 1991], and in some areas as high as 40%, principally due to the shortage of meters, illegal electricity tapping, and high distribution losses [UNDP, 1990; Nguyen Van Than, 1990].

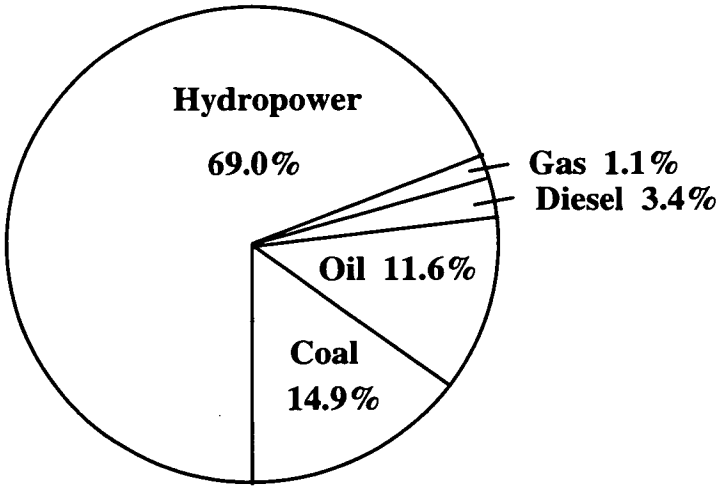
Hydropower is the source of the majority of country's electricity as can be seen from figure 4.3.

There are three separate power companies, each under the Ministry of Energy, which are responsible for their own plant and customer services. The North, South and Central regions are under the auspices of Power Company No.1, No.2 and No.3 respectively. Presently, separate grid systems exist in the North and the South of the country, whereas in the central region, which is worst served by electricity supplies, there is no unified grid and electricity is mainly obtained using old diesel plant from many different countries. There are no private utilities involved in production, transmission or distribution within Vietnam [Nguyen Van Hanh, 1992].



[Source: World Bank, 1993]

FIGURE 4.2: The Vietnamese electricity grid network



[Source: Tran Quoc Cuong, 1992]

FIGURE 4.3: Generation mix (1991) in Vietnam

Generating plant	Generation costs (Dong/kWh)	Generation costs (UScent/kWh)
Large hydropower	100	0.93
Coal	350	3.24
Diesel	>1,000	>9.26

[Sources: ECIU, 1993; pc Nguyen Duc Loc (c)]

FIGURE 4.4: Electricity generating costs in Vietnam

The cost of generating electricity from the main power supply sources is shown in figure 4.4. Although the production cost at the large hydropower sites is presently approximately US$0.01/kWh, the electricity authority in the South of the country is willing to buy electricity at US$0.035/kWh if a company is prepared to invest in hydropower projects [pc: Nguyen Duc Loc (c)]. This is likely to be feasible for medium sized schemes, although not for smaller schemes.

The distribution and transmission systems are inadequate to meet the needs of the rural or urban population, and they are likely to receive priority attention in future developments [UNDP, 1990]. Presently a 500kV line, to be completed by 1994, is being constructed to link the Hoa Binh hydropower project in the North of the country, to Da Nang in the central region and Ho Chi Minh City in the south [Adachi, 1992]. The country's short-term priorities are to expand and upgrade distribution to each province, as well as to upgrade the existing gas and diesel stations. In the medium term, coal handling and large hydropower development are expected to take priority [UNDP, 1990].

Electricity demand is projected to grow at between 7.5% and 10.1% per annum until the year 2000 [World Bank, 1993]. Even with generating capacity expected to rise to 4,500MW by 1995 [UNDP, 1990], it is considered that electricity shortages will persist until at least the year 2000 [Nguyen Van Hanh, 1992], by which time the average electricity consumption per capita is expected to rise threefold from its 1990 level [Asian Energy News, 1991]. The biggest constraint on electricity development has been the restriction the country faces in obtaining financial resources [UN, 1992 (a)]. Electricity prices do not fully reflect the true cost of generation and are very low by international standards, as government subsidies are provided. This has been partly the reason why power capacity has not risen with demand, as new schemes can not be afforded [World Bank, 1990]. The variation in electricity tariffs can be seen from figure 4.5.

User	Tariff (Dong/kWh)	Tariff (UScent/kWh)
Residential	450	4.1
Government employees	41	0.4
Foreigners	990	9.0
Pumping	190	1.7

[Source: pc: Institute of Energy]

FIGURE 4.5: Some of the electricity tariffs in Vietnam (1990)

The nominal price of electricity in the cities is 450 Dong/kWh (US$0.041/kWh), and is often much higher in rural areas where the tariff is dependent upon the extent of losses in the local grid system. In Thach That province where the bulk price of electricity is 360 Dong/kWh the local authority sells electricity at 700-800 Dong/kWh, depending upon the distance from the substation [World Bank, 1993]. In some rural areas where a local electricity supply is the responsibility of a community, charges are sometimes made in terms of commodities such as rice. For example in Cao Ky, Bac Thai province, a charge of 2kg of rice per month is made for a single light bulb connection was suggested by the commune leader. This is equivalent to the cost of running two kerosene lamps for a month [Cromwell, 1991].

4.3. RURAL ELECTRIFICATION

4.3.1. History of rural electrification

During the years between 1954 and 1975, the only electricity available in the rural areas for public use was for water pumping. It was between 1975 and 1985 that programmes to develop small rural industries, lighting and communications were established, but they were limited by the capacity of the existing power plants and distribution networks. This was a time of unsteady economic development, and no major rural electrification projects were initiated other than renovation of destroyed facilities, and the construction of mini- and micro-hydropower schemes.

4.3.2. Government policy towards rural electrification

The stated objectives of the programme of rural electrification, as set out within the framework of national development include [Nguyen Van Hanh, 1992]:

a) to improve the living standards of the rural poor and reduce the socio-economic differences between the rural and urban populations;

b) to provide a substitute energy source with a view to reducing consumption of imported fuels and fuel wood in areas subjected to intense deforestation;

c) to develop electric water pumping for irrigation and drainage, with the aim of growing several rice crops per year.

In practical terms, the government aims to speed up substantially the rural electrification programme, and to provide electricity for up to 35% of the rural population by the year 2000 [Nguyen Van Hanh, 1992]. The development strategy has the following order of priority [Nguyen Van Hanh, 1992]:

a) the vital agricultural areas (mainly rice cultivation) requiring electric water pumping;

b) areas located close to the national grid lines and district and municipalities' chief towns;

c) mountain areas and those having potential for mini- and micro-hydropower projects.

Electricity for agriculture is prioritised in order to increase production, whereas electricity supply to small industries and for lighting is stated as being provided only as a last resort [Nguyen Van Hanh, 1992], although it is often the foremost end use [UN, 1992 (a)].

The long term aim of the government is to create a unified national grid, fed by large hydropower and thermal plants, and locally supported by small-scale hydropower schemes. In order to reduce costs, it wishes to reduce the use of diesel generators, encourage off-peak use of electricity to raise the load factor, and reduce electricity theft and losses on distribution lines [Nguyen Van Hanh, 1992].

Temporary subsidies have been introduced to speed up rural electrification [Nguyen Van Hanh, 1992], such that cost effectiveness criteria do not play a decisive role in the selection of projects. The main objective of these programmes is to reduce the socio-economic gap between the richer urban population and the poor rural population via subsidies, taxation and tariff policies. In reality, however, there is only a small investment budget allocated for rural electrification, and this, coupled with the very low income of the rural population, has limited the number of projects [Nguyen Van Hanh, 1992].

Government policy statements support development of small-scale hydropower in highland areas [Cromwell, 1991]. The New and Renewable Sources of Energy (NRSE) National Programme was set up in 1980 and their programmes have included improved cooking stoves, micro-hydropower stations, biogas technology, solar, wind and rural energy planning.

4.3.3. Rural electrification agencies

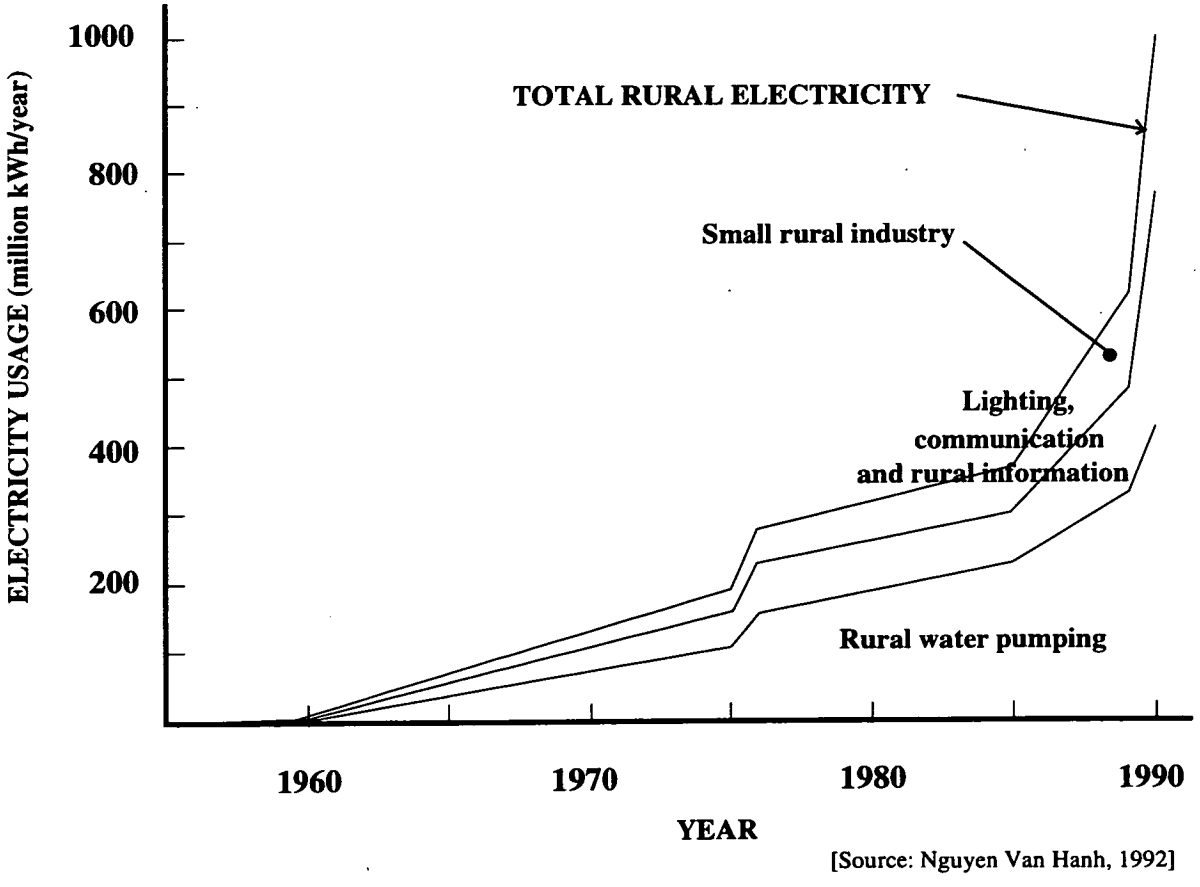
Rural electrification is under the auspices of the Ministry of Energy, through Regional Electricity Authorities, Provincial Electricity Authorities and district sub-offices [Nguyen Van Hanh, 1992]. They are responsible for all aspects of rural electrification, including the operation and maintenance of the systems, and are particularly concerned with the running of main water pumping stations and schemes providing electricity for small rural industries manufacturing export commodities. Electricity supplies for agricultural cooperatives are operated and maintained by the Electricity Sub-offices and managed by the district administrative organisations, through the agricultural co-operatives [Nguyen Van Hanh, 1992]. No private organisation presently has the right to undertake rural electrification [Nguyen Van Hanh, 1992], however, it is generally accepted that

independent users can generate electricity with schemes of up to 30kW.

Initiatives set up as part of the NRSE programme are usually run by individual families, or in conjunction with local communal groups. There has been NGO support for some rural electrification projects, in the form of assistance to district initiated projects.

4.3.4. Extent of rural electrification

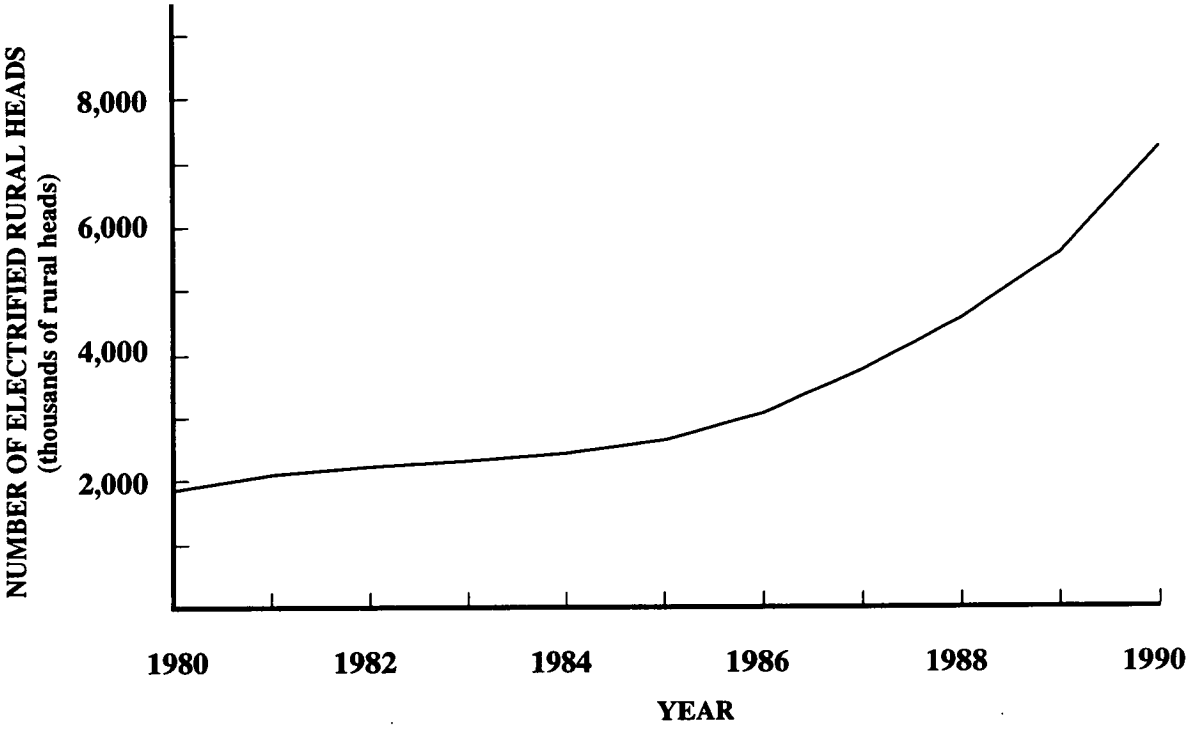
In 1990 the average annual electricity consumption per connected rural household was estimated to be 46.9kWh and this is expected to grow to between 64 and 78 kWh by the year 2000 [Nguyen Van Hanh, 1992]. Agricultural electricity consumption per rural capita was 19.8kWh/person/year in 1989, a large proportion of which was for irrigation and drainage. In 1990, 1.6 million hectares (5% of the country) was estimated to be irrigated and 1 million hectares drained, although due to the electricity shortages the demand for this sector was far from being satisfied [Nguyen Van Hanh, 1992]. The rise in electricity usage is shown in figure 4.6.



[Source: Nguyen Van Hanh, 1992]

FIGURE 4.6: Growth in electricity usage in rural areas of Vietnam

Figure 4.7 shows the growth in connections made to rural households between 1980 and 1990. In 1990, 13.9% of the rural population were estimated to receive electricity [Nguyen Van Hanh, 1992].



[Source: Nguyen Van Hanh, 1992]

FIGURE 4.7: Growth of rural electrified households in Vietnam

Most provincial capitals are being provided with an electricity supply, but local distribution lines to nearby settlements have received little attention [World Bank, 1990]. Forty eight million people live in areas where it is thought that a grid connected supply will be the most economical supply option [Cromwell, 1991], leaving over sixteen million people in areas where an isolated grid will be most economical. One million people have an electricity supply which is not connected to the national grid systems [UNDP, 1986]. As well as small-scale hydropower schemes, in some areas diesel generators are being used.

During 1990, 11% of the national electricity production was distributed to rural areas [Nguyen Van Hanh, 1992], and of this, the mountainous areas benefit the least. For example, in 1991 less than 3% of the 3.550TWh total sales of the Power Company No1 in the North of the country were distributed to the mountainous areas [Nguyen Khac Diem, 1992]. Other sources are being used, however, and in the northern province of Bac Thai,

less than 1% of the electricity to the districts is supplied from the grid [Cromwell, 1991].

Where electricity supplies are provided the low income of the rural population often means that they are not able to purchase appliances, or contribute to the cost of construction of a scheme and connection to it. There are, however, over 7,000 rural credit cooperatives which cater for the needs of households in rural and urban areas. They are most active in the South of the country which is generally more prosperous [IMF, 1989].

4.4. HYDROPOWER IN VIETNAM

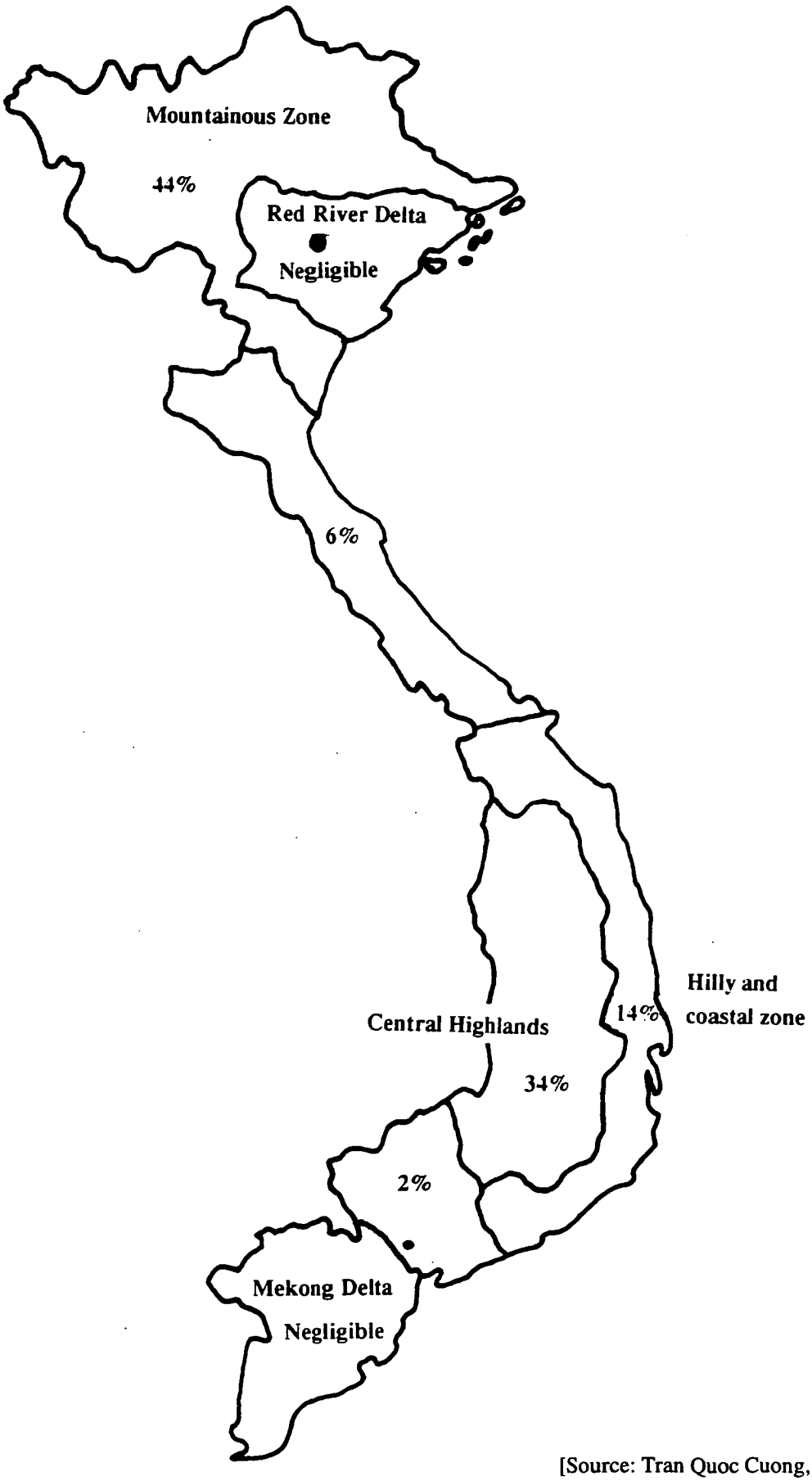
4.4.1. Introduction

Power from water has been utilised traditionally in Vietnam for hundreds of years for rice husking and for water raising using large water wheels. Hydraulic engineering skills have also been developed over a long period of time as people across the country and particularly in the river basin areas have used irrigation systems to control the flow and level of the water.

Capacity	Estimated potential (MW)	Present installed capacity (MW)	Percentage exploited
> 10MW	16,000	2,608	16.3
1MW - 10MW	1,800	62	3.4
100kW - 1MW	200	10	5.0

FIGURE 4.8: Hydropower potential and developments in Vietnam

There are over 2,200 rivers in Vietnam of length greater than 10km [Nguyen Khac Diem, 1992], of which the most important for hydropower include the Da River Basin (38% of total economically feasible potential) in the North, Xexan in the Centre (more than 9%), and the Dong Nai River Basin in the South (approximately 14%), as can be seen from figure 4.9. The economic hydro potential of the country is estimated to be 18,000MW, of which 16,000MW is for medium- and large-scale projects above 10MW, and 2,000MW of which is for sites of capacity less than 10MW [Nguyen Duc Loc, 1991]. Even with the completion of the Hoa Binh and the Tri Anh projects, only 15% of the country's economically feasible hydropower potential will have been developed [Ha Tien Luy, 1989].



[Source: Tran Quoc Cuong, 1992]

FIGURE 4.9: Map showing the distribution of economically feasible hydropower sites in Vietnam

The first modern hydropower scheme to be built in Vietnam was installed by the French in 1924 at Ta Sa, Cao Bang province. It had a capacity of 850kW and provided power for a local tin mine [Nguyen Khac Diem, 1992]. Many of the larger projects built after 1975 have been with the assistance of China, Russia and Czechoslovakia. There have been several joint ventures with foreign companies for the larger schemes installed in Vietnam. By 1975, 264 micro-hydropower schemes, and a further 26 mini-hydropower schemes had been constructed (figure 4.10). In the years between 1975 and 1985 a further 92 micro-hydropower schemes and 18 mini-hydropower schemes were installed, as were several hundred Family-hydropower units used predominantly for lighting.

Year	Total		100kW - 10MW		<100kW	
	No. of plant	Capacity (kW)	No. of plant	Capacity (kW)	No. of plant	Capacity (kW)
Before 1975	290	23,500	26	18,500	264	5,000
1976 - 1985	110	6,500	18	5,500	92	1,000
Total	400	30,000	44	24,000	356	6,000

[Source: Ha Tien Luy, 1989]

FIGURE 4.10: Small-scale hydropower construction in Vietnam until 1985

With a total capacity of around 30MW, the 400 micro-hydropower and mini-hydropower schemes installed to date represent approximately 2.5% of the economically feasible sites below 2MW [Vo Sy Huynh, 1990]. In addition there are estimated to have been approximately 3,000 Family-hydropower sets installed, with capacities between 50W and 1kW [Nguyen Khac Diem, 1992].

Most of the micro-hydropower schemes have been established either in the North of the country, in the Se San Basin, or in the Central Highlands (see figure 4.9) [Adachi, 1992]. The market demand for micro-hydropower has different characteristics in each of the three zones: North, South and Central. In the North, where average incomes are low, and there is an abundance of small streams and rivers near to population centres, 100W - 3kW units are preferred. In the South, where there is higher revenue, and ethnic communities are more likely to live higher up the valley or actually on hill tops, then 5 - 50kW schemes are preferred. Several 200kW to 1MW sites have also been integrated into the grid in these regions [Nguyen Duc Loc, 1992]. In the central region, where there is no unified grid, schemes of over 200kW are preferred by the provincial administrations, whereas the relatively poor peoples of the highland areas are more likely to benefit in the near future from Family-hydropower units and micro-hydropower schemes below 50kW.

4.4.2. Hydropower institutions

The Ministry of Energy is responsible for hydropower throughout the country, though the Ministry of Water Resources is also responsible for many of the smaller hydropower schemes under their remit for irrigation [UNIDO, 1988].

Since 1985 small-scale hydropower stations above 100kW have been constructed and operated by the Provincial Energy Boards. Schemes have been established following the priorities of the National Energy Plan, issued by the Institute of Energy and Electrification of the Ministry of Energy. The Institute of Electrical Science and Technology is responsible for ensuring the adequacy of electrical and mechanical equipment, and the Electrical Survey and Design organisation are responsible for a site's civil works [UNDP, 1986].

A diversity of organisations, institutes and authorities claim to be capable of manufacture and installation of schemes. Schemes under 100kW are often initiated by people's committees [Nguyen Thuong, 1990], with the local Energy Boards being responsible for the design, construction and operation, following the criteria for equipment selection and design specified by the Ministry of Energy [Cromwell, 1991]. Almost all micro-hydropower schemes are owned by the province, either directly, or through small power companies [Cromwell, 1991]. Recently, construction of these smaller schemes has been undertaken without foreign assistance, and Vietnamese engineers have also constructed schemes in the Lao PDR, Cambodia and Mongolia [Nguyen Thuong, 1990]. Civil work construction is often undertaken within Vietnam by the District Construction Offices. A high level of competence with hydraulics and water management is available at provincial, district and commune levels [Cromwell, 1991].

Funding for most of the schemes above 900kW has been provided by regional and cooperative financing. With smaller schemes, several cooperatives have provided the funds for their own projects, and even in the poorer mountainous areas, cooperatives have purchased equipment for pumping purposes, which in some cases has led to the production of an extra crop per year [Nguyen Thuong, 1990].

Research and development in the field of micro-hydropower is under the auspices of the Ministry of Energy. Three separate departments are involved, namely the Electricity Science and Technology Research Institute, the Energy Planning and Electrification Institute, and the Survey and Design Team. The Renewable Energy Research Centre under the Ministry of Education and Training is also concerned with research, design,

manufacture and dissemination of micro-hydropower equipment.

4.4.3. Mini- and micro-hydropower

Of the 30 stations built between 1960 and 1964 very few are still in operation [Cromwell, 1991]. The majority of the small-scale hydropower stations built since 1975 have been set up without significant foreign assistance, however, the Ministry of Energy estimates that only 65% of the stations built to date (in excess of 400), are still producing electricity. They also state that the majority of those which are still in operation are producing less than their design capacity, or are operating inefficiently, or only periodically [UNDP, 1986]. Closure of some installations appears to have occurred due, in part, to insufficient provisions being made for recurring costs for operation and maintenance. For example, in the province of Bac Thai, it is generally considered that 22 out of the existing 35 installations are no longer operating due to mechanical disrepair, compounded by lack of financial resources to enable adequate operation and maintenance [Cromwell, 1991]. The majority of schemes supported by the government agencies are generally in poor repair, in contrast to those under the management of local communities, which are in a better situation [SHP News, 1990 (b)]. The scarcity of funds for maintenance, and the lack of consideration given to the supply of spare parts, are considered to be the major, but not the only problems affecting the reliability of the schemes, as will be discussed below. The poor quality of locally manufactured equipment produced during the 1980's and the inappropriate siting of turbines have also been major factors, as will be discussed in more detail in section 4.5 on local manufacture. Reaction turbines are particularly sensitive to site conditions, and it appears the turbines have rapidly suffered from cavitation due to the inappropriate choice of turbines at many sites. The lack of scheme design knowledge and the apparent emphasis placed on producing standardised reaction turbines are particularly to blame.

Planning of individual sites is often top-down and centralised, there being little liaison with the project beneficiaries, whose views are seldom taken into account [Cromwell, 1991]. There is a lack of consideration placed upon the need for demand analysis, promotion of productive end uses, and ability to pay. The main objectives for many of the smaller schemes appears to be to provide assistance to disadvantaged ethnic minority groups, with little thought of management planning and the financial consideration necessary to ensure the up-keep of the project [Cromwell, 1991].

Most designs for schemes are undertaken without actual measurements of site head and flow measurements. Good map data is available, but this can not be a substitute for real

measurements, as there is often a large difference between measured and expected values. The need for actual flow rate measurements, for example, does not appear to be adequately appreciated, but the situation is compounded by the lack of measurement equipment [Cromwell, 1991].

Some of the larger micro-hydropower schemes (100kW and above) have been established primarily to promote agricultural development, for example for pumping stations, rice mills and some local craft industry. However, lighting is usually the main priority of the provincial and district officials involved in the promotion of micro-hydropower and Family-hydropower schemes [Cromwell, 1991], and other end uses are seldom considered. Direct mechanical processing from a hydropower unit is rare in Vietnam. In Bac Thai province for example, only five of the forty-four schemes built use some form of directly driven device. Schemes are often used in conjunction with battery charging to supply electricity for lighting and sometimes television for those people without a direct connection. Some small schemes have been built for productive end uses such as wood processing, for example in Bac Thai province where several 10kW to 20kW units are being utilised for this purpose [Hanoi Moi, 1991].

Most organisations have not wanted to take the responsibility of connecting their systems to the grid. The lack of adequate equipment and expertise at the local level has meant that in some cases two turbines have been installed, but only one is in operation at any one time, as the operators are not able to synchronise the two generators [pc: Nguyen Duc Loc (c)].

Problems arise with some isolated supplies, where the number of connections are not limited, resulting in large voltage and frequency fluctuations. Often no method of prevention is used to prevent over-extension of the supply, and poor voltage regulation is accepted with resignation. This leads to both a poor quality of lighting and also limits the usefulness of the supply for other end uses. A vicious circle has sometimes arisen whereby people fit higher wattage bulbs, in order to counteract the effects of reduced voltages, which has caused lights to dim further. Stability of supply is also influenced by the type of governing used, and for most schemes with capacities below 100kW, only manual governing is used. Regulation is poor, but considered to be adequate for the mountainous areas [Nguyen Khac Diem, 1992]. The oldest sites using Vietnamese made equipment include a 160kW pelton turbine and a 96kW Francis turbine, in Ha Son Binh province, which have been operating without speed governors since they were installed over 20 years ago. For schemes with larger capacities a mechanical hydraulic governor is most often used, the design for which is based upon Chinese technology [Leyland

Consultants, 1988].

Labour costs in Vietnam are very low and thus civil work costs are low, especially if local materials are used. In contrast the cost of transportation of equipment to the sites is high, due to the difficult terrain and poor road infrastructure.

4.4.4. Family-hydropower

In Vietnam, there are estimated to have been as many as 3,000 Family-hydropower units installed, mainly in the North of the country. In Bac Thong District of Bac Thai province alone, 480 schemes have been installed [Hanoi Moi, 1991]. The major phase of this expansion of the use of Family-hydropower units in the district started in 1990 when the district authorities bought 25 Chinese-made Family-hydropower units, selling them on to the public for the same price. In some provinces they are subsidised by the local government. In Bac Thai province for example, subsidies were at one time available for 50-100% of the cost of a limited number of Family-hydropower units, as well as there being technical support available to advise on installation and operation. An estimated 1,500 families have so far benefited from 300W units, each of which is used by two to three families, and there are plans for a further 170 more to be bought by the provincial administration in the near future [Hanoi Moi, 1991], whilst others will continue to be bought in the market place. The relative low cost of the equipment has established a large rural market with many individuals buying Chinese equipment direct from the market place, where they receive a six month guarantee from the Vietnamese supplier [Cromwell, 1991]. In the market places of many of the country's cities and towns, 100W units can be purchased for as little as US$28. Figure 2.19 shows the cost comparison for some of the different types of equipment available in Vietnam. The Chinese equipment's cost is marked up by approximately 30-40% before being sold in the market place in Vietnam.

Chinese equipment is imported through the Cao Bang border [pc: Nguyen Duc Loc (a)], but it is preferred over the Vietnamese equipment by both individuals and district authorities, due to its low price and its lighter weight, although equipment made in Vietnam is generally considered to be of better quality than the Chinese units. Over 100 units made by the Renewable Energy Research Centre (RERC), in Hanoi, have been sold [pc: Nguyen Duc Loc (c)], but Chinese Family-hydropower equipment is still more popular, as it is established in the market and is considerably cheaper for its stated capacity. However, the stated capacity of the Chinese equipment is often considered to be greater than that which the equipment can actually deliver. Tests on a 200W Chinese

turbine produced a maximum output of 84W (0.4A @ 210V), whereas 200W Vietnamese equipment provided maximum power of approximately 200W (1.0A @ 200V) [pc: Nguyen Duc Loc (a)]. The Chinese equipment comes in two forms, one using a fixed blade propeller with guide vane as shown in figure 2.20, and the other using an impulse turbine for higher heads. Bamboo is often used as piping for the latter model.

A 1kW Vietnamese-made unit which operates from a 2m head has been shown to have a payback period of under a year, when the electricity is sold within the village [Nguyen Duc Loc, 1991]. In comparison to the 1kW model, the 200W model has a lower efficiency and higher cost per unit of energy, but the price of US$350 for the larger model is approximately twice that of the annual income for a typical Vietnamese farmer, and it is substantially heavier, making transportation difficult. The RERC, which makes the Vietnamese equipment, has so far been subsidising most of the units it has sold within the country.

Many Family-hydropower units are used in conjunction with a battery, and they are predominantly used for lighting and sometimes television, radio and other low power equipment. The most common battery for the Family-hydropower units has a capacity of twenty ampere-hours, a cost of US$3, and has a life span of approximately one year [pc: Nguyen Duc Loc (c)]. Battery charging is often the only economically feasible method by which a family can obtain an electricity supply in many rural areas.

A 100W Chinese-made Family-hydropower unit may typically supply 80W for 3 hours/day, normally for lighting (both bulbs and fluorescent tubes are used). At a cost price of US$28 for the set, if maintenance and operation costs are assumed to be negligible, figure 4.11 shows that the purchase of a Family-hydropower unit would become economical, in comparison to battery charging from diesel, if it operated for approximately sixteen months. This is making several assumptions, but it is clear that in comparison to the other sources for electricity available in most rural areas, Family-hydropower can often be the cheaper option. However, these costs are still very high for most rural Vietnamese, and it is only the more wealthy who can afford them. With petroleum product taxes set to increase [World Bank, 1993] the cost of battery charging is likely to increase also.

Family-hydropower is predominantly used in the northern hill areas where there is no other source of electricity. Such machines are also used in the more prosperous lowland areas where it is possible to obtain a one to two metres head in the irrigation canals. Figure 2.21 shows three Family-hydropower units used by four families for lighting in the

Family-hydropower unit (100W)

Typical output	80W
Usage per day	3 hours
kWh per month	7.2kWh

Family-hydropower equipment cost	US$28
Installation costs	US$9
Total family-hydropower costs	**US$37**

Battery charged by diesel

60Ah, 12V battery
@ 90% discharge & 90% energy recovery

Effective kWh per charge	0.58kWh
No. of charges/month for 7.2kWh	12.4 charges

Cost per charge	US$0.19
Cost per month	US$2.36
Cost of charging a battery for 16 months	**US$37.76**

FIGURE 4.11: Break-even time for 100W Family-hydropower units

southern province of Dong Nai. The land around is relatively flat, being in an area of lowland rice fields, approximately 120km from Ho Chi Min City and 10km from the main road. Sometimes the turbines were disconnected at night and taken inside for security reasons [pc: Nguyen Duc Loc (d)].

In some districts the authorities have assigned technicians to train the local villagers in the operation of the equipment and to help in their installation. However, most are installed by the individual purchasers, and not always to an optimum.

4.4.5. Future plans

The Institute of Energy in Vietnam believes there to be a further 2,500 economically feasible sites with capacities between 5kW and 100kW [Ha Tien Luy, 1989], and over 500 sites between 100kW and 10MW, as can be seen from figure 4.12. At approximately 500 of these sites irrigation systems are already in existence, and they would therefore require a relatively low level of investment [Nguyen Khac Diem, 1992]. Figure 4.13 shows a breakdown of the mini-hydropower projects which are considered to be economically feasible. Between 160 and 200 mini- and micro-hydropower stations with

Installed capacity	Number of plants	Total capacity of plants (MW)
100kW - 10MW	>500	1,400 - 1,800
< 100kW	> 2,500	100 - 200

[Source: Ha Tien Luy, 1989]

FIGURE 4.12: Economic feasibility of small-scale hydropower projects

Capacity (kW)	Number of projects
200 - 400	108
400 - 600	56
600 - 800	43
800 - 1,000	36
1,000 - 2,000	106
Over 2,000	175

[Source: SHP News, 1989]

FIGURE 4.13: Mini-hydropower projects considered to be economically feasible in Vietnam

a total installed capacity of over 100MW were planned for construction between the years 1985 and 2000 [Zenaida Santos, 1992], but these plans are apparently behind schedule. Renewed interest has recently been shown in their development, with the Vietnamese Prime Minister's intervention. A further 250 schemes of capacities less than 2kW are planned for construction before the year 2000 [Leyland Consultants, 1988], though this figure is likely to be considerably higher if privately purchased Family-hydropower schemes are also taken into account. All of the different organisations involved with micro-hydropower development in Vietnam suggest different forecasts and plans for future developments. If a further 150 to 200 stations are to be built, providing at least a further 100MW before the year 2000, it has been estimated that US$200 to US$400 million will be required [Dam Xuan Hiep, 1991]. This will require concerted government, and/or foreign investment.

The major macro-constraints affecting the development of the small-scale hydropower resources in Vietnam include [Nguyen Van Than, 1991]:

- the shortage of capital;

- the low income level of the population;
- the subsidies to other forms of energy;
- the lack of information concerning new technologies and methods;
- the cost of operation and maintenance.

4.4.6. Requirements for small-scale hydropower development in Vietnam

One of the main failures of the Vietnamese approach to small-scale hydropower development has been the lack of provision for financial security to pay for project repair. With so many sites now in disrepair, one of the most cost-effective ways forward will be to refurbish these sites, and create a situation whereby repair and maintenance can be more easily achieved. Increased awareness of the need for demand analysis, load management and financial management are also required.

There is a need for automatic control for the schemes below 100kW in order to increase the quality of the power produced and eradicate the need for continuous manual operation. ELC technology may be the way forward, but there is a general lack of knowledge about recent developments in new, low cost controller technologies, such as ELCs and IGCs.

A consistent funding policy is required for Family-hydro power units, to prevent confusion about future costs of equipment, which in the short term will cause people to refrain from purchasing. Family-hydropower units are not always optimally installed, even with instructions being provided. Increased assistance to purchasers and installers is required.

Other requirements are described below.

- Actual measurement of dry season and wet season flow rates should be obtained before a system is designed. More measuring equipment will be needed for this to be achieved.
- Improved de-silting mechanisms are needed to reduce erosion of the turbine blades.

- There is a need for improving the skills of project designers with respect to choosing appropriate turbines for installation at given sites.

4.5. LOCAL MANUFACTURE OF HYDROPOWER EQUIPMENT

4.5.1. Introduction

Before 1975 all the small-scale hydropower equipment installed in Vietnam was imported from abroad [Ha Tien Luy, 1989]. During the 1980's the demand for turbines in Vietnam rose dramatically, concurrently with the rapid evolution of local manufacturing capabilities. Pump turbines used for irrigation purposes are still mainly imported from China, however, the majority of micro-hydropower generating equipment is now manufactured within Vietnam. The major companies involved in the production of small-scale hydropower equipment in Vietnam have been:

a) Machine Tool Factory No.1, Hanoi;

b) Dong Anh Electrical Equipment Factory, Hanoi;

c) Hydro Electric Research Centre, Hanoi;

d) Electrical Equipment Designing Enterprise, Hanoi;

e) Hydro-power Equipment Centre, Hanoi;

f) Governor Research Enterprise, Hanoi;

g) Renewable Energy Research Centre, Hanoi;

h) Mechanical Engineering Factory, Ho Chi Minh City;

i) Research Centre for Thermal Research & Renewable Energy, Ho Chi Minh City.

A summary of their work is given in section 4.5.9.

4.5.2. Government policies towards local manufacture of hydropower energy equipment

The hydropower sector in Vietnam has been dependent upon a combination of state run large manufacturers and imports [Cromwell, 1991]. The commonest source of imported turbines is China, with others coming from the old Republic of Czechoslovakia, Japan, France and Germany [SHP News, 1990 (b)].

Government policy statements support development of small-scale hydropower projects in highland areas, and also the expansion of local manufacturing capacity [Cromwell, 1991], however, a supply policy has not been fully stated. The liberalisation of the country's economic policies is presently enabling organisations other than state owned companies to become involved in the manufacture of equipment, and foreign investment is beginning to be strongly promoted. One of the country's stated main short-term priorities is to modernise its electrical equipment producing manufacturing plant in order to produce better quality and a wider range of modern products [UNDP, 1990].

4.5.3. Acquisition of technological capabilities

Business and foreign investment regulations in Vietnam are amongst the most liberal of all developing countries [REMIT Consultants, 1992]. With investment laws being so new, many have not been fully tested and there is still wide scope for interpretation, with the possibility that laws may change on a regular basis. Investment remains constrained by this uncertain business environment, which is likely to deter some potential investors.

New foreign investment laws in Vietnam aim at expanding economic development and increasing exports. The State Committee for Cooperation and Investment was created in 1988 to manage and administer all direct foreign investment. The law guarantees fair and equitable treatment for foreign investors and provides protection to foreign investors against nationalisation. Industrial property rights of the transferrer of the technology are protected through domestic law. Support for technology transfer to Vietnamese organisations is available from the Consultancy Centre for Technology Transfer and Investment, and also from the Investment Consultancy and Technology Transfer Company (Investconsult), both in Hanoi.

From 1990, private Vietnamese firms have been allowed to enter joint ventures with foreign firms. Joint ventures are being promoted and although 100% foreign-owned companies are permitted, they are not encouraged [REMIT Consultants, 1992]. Forms of

investment as laid out by the Law on Foreign Investment cover: contractual ventures; joint ventures; 100% foreign owned ventures. The Foreign Investment Law was amended in 1992 to encourage Build-Own-Transfer, Built-Transfer and Build-Own-Operate investments. No ceiling is set on the level of foreign ownership in a company, however, the foreign investor's share may not be less than 30% in a joint venture. Also the managing director, or the first deputy managing director of a joint venture must be a Vietnamese citizen. Regulations state that the technology to be transferred should be necessary and suitable for the venture to produce significant socio-economic effects or increase an existing enterprise's competitiveness in the international market. The law states that for joint ventures, the technology should [UNCTAD, 1992]:

1) be capable of bringing considerable improvement in the appearance and quality of the products, and an increase in the output; and,

2) be capable of creating new products which are urgently needed in the country, or of producing import substitutes; and,

3) should result in considerable savings in terms of raw materials and energy.

Tax incentives given to 100% foreign-owned projects. The import and export taxes for some hydropower components shown below indicate that there is some protection provided for local manufacturers of small generator production against imports.

Product	**Tax Rate (%)**
Hydraulic turbines, water wheels and parts thereof	0%
A.C. generators <75kW	15%
A.C. generators >75kW & <375kW	10%
A.C. generators >375kW	0%
Pumps (not hand operated)	0%

[Ministry of Trade and Tourism, 1992].

The country has many skilled engineers who have been trained both within Vietnam, and also in the old Eastern-bloc countries. All components required for a mini-hydropower, or micro-hydropower scheme are presently capable of being manufactured within the country, and equipment for wooden water-powered rice hulling devices and water raising devices has been traditionally made in Vietnam for hundreds of years.

Vietnam has developed its modern manufacturing capabilities by copying foreign small-scale hydropower equipment, mainly Chinese, and in some cases improving upon it. Some organisations have also used turbine runner profiles and designs obtained from Russia, Czechoslovakia and France. In very few cases was permission sought from the original manufacturer of the equipment. The emphasis upon copying foreign designs has arisen mainly due to the scarcity of foreign capital, which has limited the possibilities for other forms of agreement. No joint ventures have been undertaken, though both a Japanese and a French company have in the past expressed an interest to do so. Foreign companies are now becoming more interested in the market, however, they are likely to be concerned about the possibility of their equipment being copied.

4.5.4. Turbines

The first two turbines to be design and manufactured in Vietnam were 200kW Francis units, installed and still operating at the Song Cung station, Quang Nam - Da Nang province [Nguyen Khac Diem, 1992].

Figure 4.14 shows the capabilities of the Vietnamese turbine manufacturers.

Turbine type	Power (kW)	Head (m)
Francis	30 - 2,100	10 - 100
Kaplan	5 - 1,000	8 - 15
Pelton	20 - 800	30 - 240
Crossflow	5 - 600	5 - 60

[Adapted from: Ha Tien Luy, 1989]

FIGURE 4.14: Manufacturing capabilities of Vietnamese factories

The two major manufacturers of turbines during the 1980's are no longer producing turbines. Between 1983 and 1988 the Dong Anh Factory and its sister organisation at Yen Vien, manufactured approximately 200 units of up to 5kW capacity, and 40 units in the range 10kW to 2,100kW [pc: Cong]. Around this time the Machine Tool Factory Number One produced approximately 50 Francis, Pelton and Kaplan turbines, with capacities between 20kW and 1,500kW [pc: Tran Hoang Chinh]. The majority of their turbines produced only 50% to 70% of the expected power capacity [Dam Xuan Hiep, 1991], principally due to poor design.

The original design for the largest turbine produced, a 2,100kW machine, came via an agreement with Czechoslovakia [UNIDO, 1988], as part of a State Level Science Project [Nguyen Khac Diem, 1992]. The largest site installed with domestically produced equipment is a 3,000kW scheme in Quang Nam - Da Nang province [Nguyen Khac Diem, 1992].

Most of the smaller Francis and propeller turbine blades are made from steel plates, which are rolled and welded [Nguyen Khac Diem, 1992], with the steel plates being imported from Russia [Adachi, 1992]. For larger turbines, each blade is sand cast, ground, polished and then a chrome finish is added before each blade is welded to the hub to form the turbine [pc: Tran Hoang Chinh]. The stages of production for each blade are shown in figure 4.15. The chrome layer adds between 6% and 8% to the efficiency of the blade to produce an 80% to 90% turbine efficiency [pc: Nguyen Duc Loc (a)]. The casting methods used in Vietnam are not capable of producing accurate, single cast turbines [pc: Nguyen Duc Loc (c)], and casting each blade separately makes it easier to work on the blade surfaces.

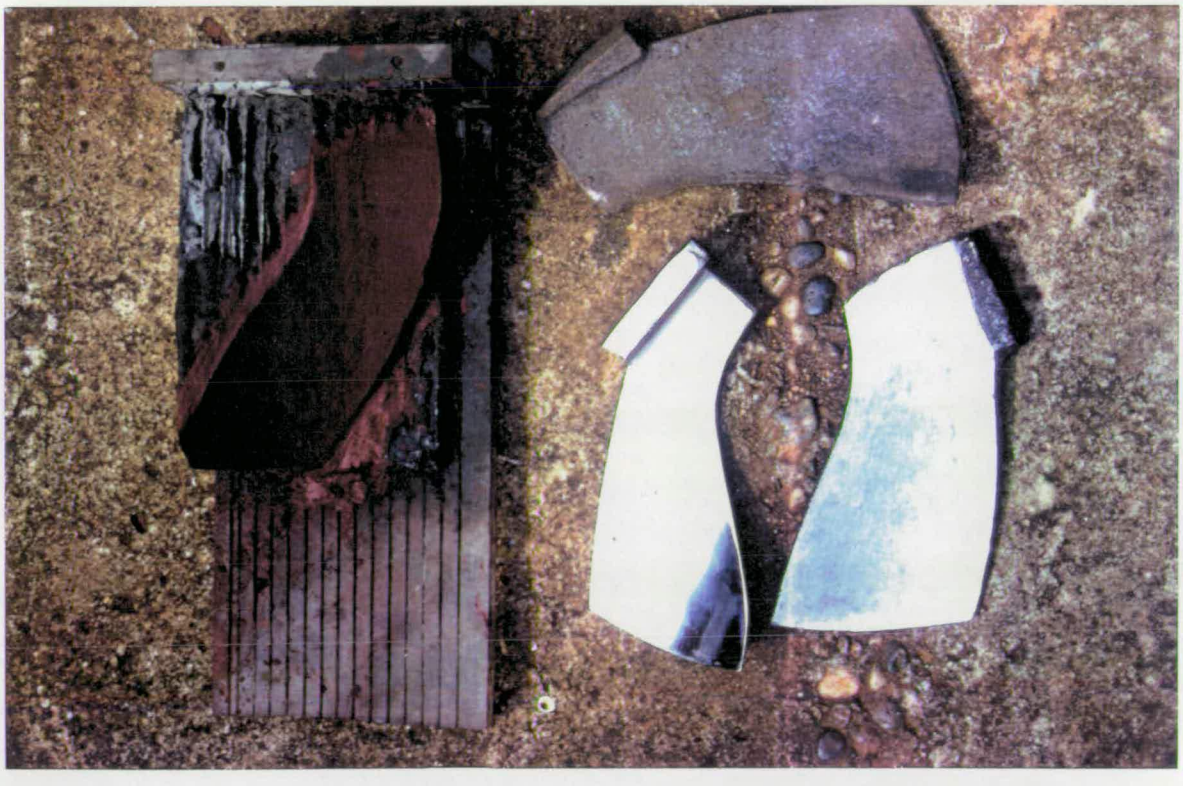


FIGURE 4.15: A Francis turbine blade at various stages of production: sand cast, ground and polished, and chrome finished

Many of the casings for Francis turbines are cast in two parts, vertically split and bolted together. Larger casings have a scroll casing made of conically rolled steel plate sections, with cast covers and stay-rings welded together [UNIDO, 1988]. Sand and centrifugal casting equipment is also used to produce guide-vanes, runner hubs and rims, labyrinth seals, bronze bushings and white metal bearings [UNIDO, 1988]. Bronze casting is also performed, but the cost of bronze is comparatively very high, compared to steel, and it is seldom used [pc: Nguyen Duc Loc (c)].

Turbines with capacities greater than 5kW have been generally funded originally directly from central government, through the Ministry of Energy, and more recently from local authorities. The rehabilitation of schemes using Vietnamese made equipment, often designed by copying the original foreign working equipment, is now taking place at many of the old hydropower sites. One hydropower project in the South of Vietnam which used French equipment has recently been renovated with equipment manufactured in Vietnam, and now has a higher capacity than had been the case over the last years of the original equipment's life. The scheme has two 1,250kW and two 300kW turbines [Vo Sy Huynh, 1990].

4.5.5. Generators

Hundreds of diesel generator sets were imported into the country during the war years [Nguyen Thuong, 1990], and the rehabilitation of these old diesel sets has proved to be a cheap and reliable source of generators, essential for small-scale hydropower developments in Vietnam [Nguyen Khac Diem, 1992]. They were first used in this way in the early 1980's, and the first unit to be utilised is still in operation, in conjunction with the first domestic Francis turbine. The old diesel generators need to be repaired and reinforced to withstand high runaway speeds associated with hydro turbines and there is often a need for the shaft to be reshaped in order to accommodate a turbine runner [Nguyen Khac Diem, 1992].

Generators are also now manufactured within Vietnam with capacities of 5, 30, 50, 160 and 240kW [Ha Tien Luy, 1989], and the Machine Tool Factory Number One is capable of producing generators with capacities of up to 400kW [pc: Tran Hoang Chinh]. The first domestic alternator was designed and made at the Electric Equipment Manufacturing Plant as part of a scientific project funded by the government. It was a 250kVA, 750rpm, 50Hz machine designed for operation with a Francis turbine, and passed tests to Russian standards [Nguyen Khac Diem, 1992]. Carbon brushes and all ferrous materials for use in generators are imported into Vietnam [pc: Nguyen Duc Loc (c)].

The cost of locally manufactured generators is comparatively high. For example, a 500kW locally made generator would be approximately US$30,000, compared to the cost of a reconditioned diesel generator being around US$15,000, and an imported Chinese generator being approximately US$25,000 [pc: Nguyen Duc Loc (c)]. At present Chinese generators are being used extensively for small-scale hydropower schemes.

4.5.6. Governors

Mechanical-hydraulic governors are the most widely used type of governor in Vietnam. As well as Chinese governors being used in the country, several Vietnamese organisations have manufactured mechanical-hydraulic governors. The Electrical Equipment Designing Enterprise produce a mechanical hydraulic governor based upon a French design, and several other organisations, including the Machine Tool Factory Number One, have produced their own. Manual governing is relied upon for nearly all schemes of capacities below 100kW due to the high cost of the governors [pc: Cong]. This is a source of problems at some sites, where a full time operator is required. The Renewable Energy Research Centre (RERC) in Hanoi have built a 2kW ELC [UNIDO, 1988], and a dissipative load similar to an ELC, though it only uses one on/off switch for one of their 1kW units.

In 1991 the government invested 100 million Dong (US$9,300), allocated by the Centre for Scientific and Technological Information and Services of the Ministry of Energy, to develop an electronic speed governor. This money and a further 200 million Dong (US$18,500) was to cover design and development, as well as the production of the first 20 units [Nguyen Khac Diem, 1992]. Specifically designed for schemes with capacities between 100kW and 1MW, the governors were developed to cope with the specific conditions present in Vietnam. Czechoslovak governors were originally used, but were judged to be incapable of working in conjunction with the rehabilitated generators and the periodic loss of load, which are prevalent at many of the Vietnamese sites. The electronic speed governors have so far been installed with a 500kW Francis turbine at Iadrang II, Gia Lai-Kontum province and with an 800kW pelton turbine, and they appear to be operating well [Nguyen Khac Diem, 1992].

4.5.7. Local manufacture of Family-hydropower equipment

The majority of Family-hydropower equipment available in Vietnam is imported from China, although similar equipment is now being manufactured in Hanoi, where the RERC, is presently manufacturing 200W and 1kW Family-hydropower sets, which it is

selling locally for US$75 and US$350 respectively. These are more expensive than equivalent Chinese equipment, but they are more efficient and provide greater power. The organisation developed its manufacturing capabilities by copying and improving upon the available Chinese equipment.

The blades of the Vietnamese-made turbine are cast, and welded on to the shaft, which connects directly to the generator. Unlike most generators used for micro-hydropower schemes in Vietnam, the Family-hydropower generators are designed and manufactured specifically for their task. The generators are six-pole permanent-magnet machines, providing a 220V a.c. supply, with the permanent magnets being obtained from Poland [pc: Nguyen Duc Loc (c)]. The RERC 1kW equipment also provides a 12V d.c. output for battery charging, and incorporates a single-relay device which provides approximately 30% extra loading via a water-cooled ballast. This is exceptional, as most Family-hydropower units typically have no governing or protection devices, and thus the voltage varies greatly with the load.

4.5.8. Other equipment

The country's manufacturing industry, which is principally centred around Hanoi and Ho Chi Minh City, is involved in the manufacture of many other types of electrical and mechanical equipment. Although Vietnam has been severely affected by its isolation from most Western countries and has been unable to obtain major World Bank loans, the ingenuity and determination of its people, as well as support from old Eastern-bloc countries in the past, have allowed Vietnam to build up a capable industrial base.

The Dong Anh factory manufactures transformers in the range 25kVA to 25,000kVA [pc: Cong], high voltage circuit-breakers, aluminium transmission cables, switch boards, insulators, generators and motors. Steel penstocks, conical draft-tubes and expansion joints have also been made at the factory. Butterfly valves with diameters up to one metre are also made, with the valve body, casing and flanges being made from cast steel [UNIDO, 1988]. Hydromec of the Ministry of Hydrological Resources, Ho Chi Minh City, have been involved in several turn-key and joint venture projects for which they have manufactured penstocks and intake gates [Phan Khanh, 1992]. Several other companies are producing similar equipment.

4.5.9. Assessment of companies involved in manufacture of hydropower equipment

Figure 4.16 show a summary of the capabilities and deficiencies of the companies involved in the local manufacture of turbines and other hydropower equipment within Vietnam, as described in more detail below.

FACTORY	TURBINES MANUFACTURED	CAPACITIES OF TURBINES	PRESENTLY PRODUCING	COMMENTS
MACHINE TOOL FACTORY No. 1	FRANCIS, KAPLAN & PELTON	20 - 1,500kW	NO	PROBLEMS WITH METAL QUALITY AND TURBINE EFFICIENCY.
DONG ANH ELECTRICAL EQUIPMENT FACTORY	FRANCIS, KAPLAN, BANKI & PROPELLER	5 - 2,000kW	NO	PROBLEMS WITH METAL QUALITY & TURBINE EFFICIENCY. PRODUCED APPROX 200 TURBINES BETWEEN 1983 &1988.
HYDRO ELECTRIC RESEARCH CENTRE	FRANCIS	UP TO 200kW	YES	OVER 10 SCHEMES SO FAR PRODUCED. GOOD TURBINE EFFICIENCY & RELIABILITY, THOUGH TURBINES ONLY HAVE 3 YEARS IN OPERATION.
ELECTRICAL EQUIPMENT DESIGNING ENTERPRISE	FRANCIS, KAPLAN, PELTON & BANKI	10 - 2,100kW	YES	OVER 20 SCHEMES MANUFACTURED. 5 SCHEMES INSTALLED IN 1991.
RENEWABLE ENERGY RESEARCH CENTRE	FRANCIS & FAMILY HYDRO	200W - 1,250kW	YES	MAINLY PRODUCES 200W & 1kW FAMILY HYDRO UNITS. SUB-CONTRACTED FOR OTHER WORK.

FIGURE 4.16: Capabilities of the main manufacturers of hydropower turbines in Vietnam

Machine Tool Factory No.1, Hanoi

This factory, under the direction of the Ministry of Heavy Industry in Hanoi, is one of the largest factories in the country, employing around 1,200 people [pc: Tran Hoang Chinh]. They have a large machine tool workshop and heat treatment facilities, and have manufactured many turbines and associated equipment in the past, including Francis, Kaplan and Pelton turbines in the range 20kW to 1,500kW. The largest Kaplan turbine, a 1,000kW unit, to be made and installed in the country was produced here [Nguyen Khac Diem, 1992]. They have also produced mechanical hydraulic governors and turbine casings, and are capable of manufacturing generators up to 400kVA.

The major reasons why they are no longer producing turbines are:

a) poor turbine reliability, with the quality of their cast blades being variable;

b) poor turbine efficiency, due to inadequacies in the design of the blade profiles, though they are generally considered to be of higher efficiency than equipment

produced at the Dong Anh factory [pc: Nguyen Duc Loc (b)];

c) low return on investment of turbines in comparison to other mechanical equipment which the company is capable of manufacturing;

d) a change from direct funding from central government (see section 4.5.11), to purchases from the provincial administrations for small-scale hydropower projects, has meant that the number of schemes per year has reduced and funding has become more problematic.

Dong Anh Electrical Equipment Factory, Hanoi

Between 1983 and 1988 the Dong Anh Factory, owned by the Ministry of Energy, in conjunction with its sister organisation at Yen Vien, produced around 200 Francis, Kaplan, Banki and Propeller turbines and associated equipment in the range 5kW to 2MW. The factory produced several standard designs as well as one-off units [Leyland Consultants, 1988]. Many of the schemes using their equipment are now not working, and the company is no longer manufacturing turbines. Their main problems were due to the lack of adequate de-silting mechanisms at the sites, the inappropriate siting of turbines, and the lack of knowledge concerning how to design a good profile. The efficiency of their turbines was often less than 70% [pc: Nguyen Duc Loc (c)].

The higher profitability of producing other electrical equipment is the stated reasons why the company is no longer manufacturing hydropower equipment [pc: Cong]. The diversity of equipment produced at the factory and the low number of turbines per model, made turbine production difficult both at Dong Anh and at Yen Vien. The company is presently devoting its capabilities towards manufacturing transformers and components for the 500kV North-South transmission line. They do not want to put aside completely the prospect of manufacturing further turbines, however, the present director of the company is not interested in restarting production of hydropower equipment unless there are prospects for large profits [pc: Cong].

The geometric accuracy of the components was considered to be poor, and the surface finish of water conveying parts could have been improved. The runner vanes were very thick compared to the runner size, which leads to increased sensitivity to cavitation and reduced efficiency. The efficiency of the Dong Anh equipment could have been improved by reducing the clearance between the runner and the casing [UNIDO, 1988].

Turbine type	Capacity (kW)	Head (m)	Turbine & generator costs (US$)	Governor costs (US$)
Crossflow	5	15	700	-
	10	16	1,600	-
	20	30	3,000	-
	30	60	7,000	2,800
	120	55	15,000	4,000
	400	55	50,000	5,500
Francis	100	17	20,000	4,500
	200	22	30,000	4,500
	200	60	26,000	4,500
Propeller	10	8	1,400	-
	60	10	8,000	4,000
	200	11	28,000	4,500
Pelton	200	150	30,000	4,500
	180	120	22,000	4,000
	425	130	45,000	4,500

[Source: pc: Hoang Van Thang]

FIGURE 4.17: Cost of equipment from the Hydro Electric Research Centre

Hydro Electric Research Centre, Hanoi

This organisation has been producing turbines for the last three years and is considered to be one of the most competent. They have produced around ten Francis turbines, of capacities up to 200kW, with efficiencies of around 85% [pc: Hoang Van Thang]. The equipment appears to be of better quality and higher efficiency than other Vietnamese-made equipment, however, with only three years of manufacturing experience it is not yet possible to assess fully their reliability. Figure 4.17 shows the costs of turbines, generator and governors, quoted for some of their equipment in 1992. It can be seen by comparison to figure 2.5 that these costs are considerably lower than those which are generally acceptable for micro-hydropower development. Figure 4.18 shows a 10kW propeller turbine made at the factory.

Members of the organisation, with 26 permanent staff and a pool of six expert consultants, have been producing hydropower equipment for about ten years. The

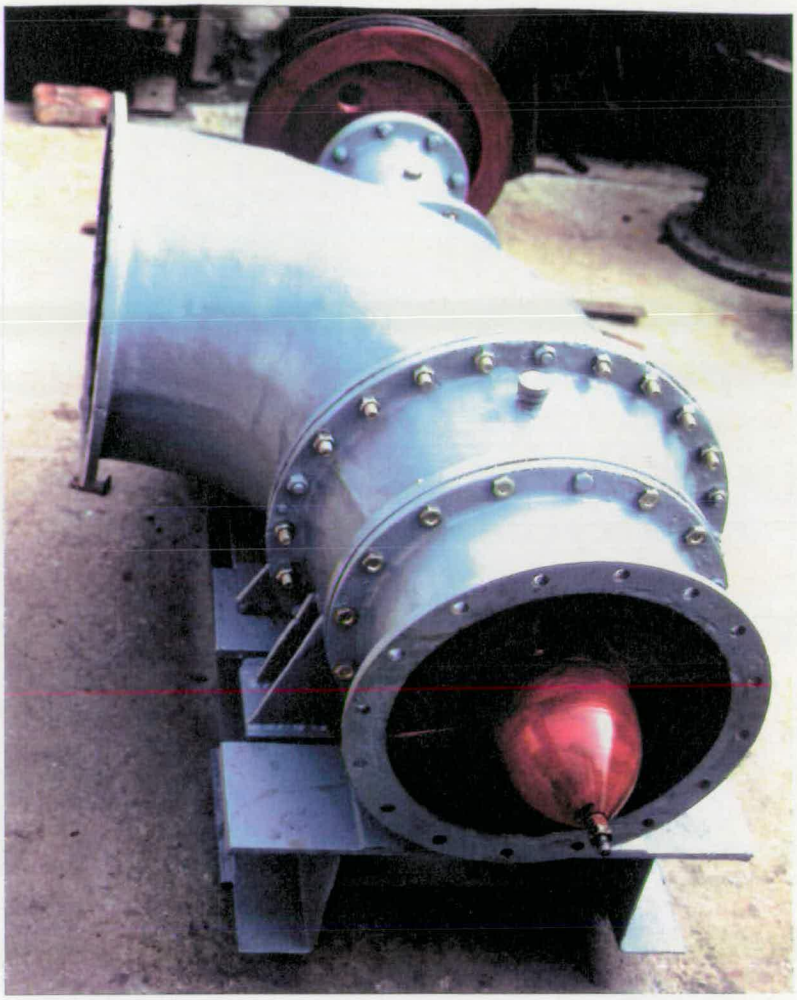


FIGURE 4.18: A 10kW propeller turbine produced at the Hydro Electric Research Centre

organisation is part of the Institute of Hydraulic Research, of the Ministry of Water Resources.

Electrical Equipment Designing Enterprise, Hanoi

This organisation, part of the Electrical Equipment Producing Company under the direction of the Ministry of Energy, has installed over 23 small-scale hydropower schemes both in Vietnam and abroad in the last ten years. These have included six Kaplan turbines (10-400kW), two Pelton turbines (180-425kW), six Francis turbines (70-560kW) and nine crossflow turbines (10-400kW) [Nguyen Khac Diem, 1992]. In conjunction with other workshops they are capable of designing and producing crossflow turbines up to 400kW, Kaplan up to 400kW, Pelton up to 800kW and Francis up to 560kW. All schemes produced by the Electrical Equipment Designing Enterprise in the last 10 years are reported to be working well [Nguyen Khac Diem, 1992]. In 1991 they

were involved in the installation of five schemes. They have approximately 40 engineers who are involved in the design and installation of equipment, whilst manufacture is sub-contracted locally. For schemes with a capacity above 100kW they produce a mechanical hydraulic governor based upon a French design.

Hydropower Equipment Centre, Hanoi

This factory on the outskirts of Hanoi has manufactured pumps and other mechanical equipment for many years. Recently it has been contracted to manufacture the casing and penstock for several of the turbines manufactured by the Hydro Electric Research Centre. They have a large machining workshop, as well as welding and casting capabilities, and as one of the main factories of the Ministry of Water Resources, they have produced many pumps and other hydraulic equipment.

Governor Research Enterprise, Hanoi

This is a government funded organisation set up two years ago to overcome the problems encountered with the governors previously made in Vietnam. They are presently able to make mechanical hydraulic and electronic hydraulic governors.

Some of the most expert people in the field of governor technology in Hanoi have been gathered together for this project. In the near future they hope to establish a private company to carry on production, but at present manufacture is sub-contracted to local workshops. Six employees are involved with design, research and final assembly of the products.

Eight governors have been produced so far and a further ten are on order. They are being used for schemes with capacities above 100kW, and the maximum capacity for which they envisage the equipment will be useful is 5MW.

Renewable Energy Research Centre, Hanoi

This centre is under the direction of the Ministry of Education and Training and has close connections with the Polytechnic University in Hanoi, where it is situated.

Presently the centre is manufacturing Family-hydropower units and micro-hydropower turbines of capacity 200W, 1kW, 3kW, 5kW, 10kW, as well as being subcontracted to undertake work on some components of larger units. Efficiency of the RERC 1kW

turbines is estimated to be between 83% and 85%. So far they have sold, amongst others, over thirty 1kW, fifteen 5kW and fifteen 10kW units [Vo Sy Huynh, 1990]. They are also involved in the design and production and finishing of turbine runners (as shown in figure 4.19), the main turbine construction for which has been undertaken by the Hydro Electric Research Centre. One of the directors has been involved in the rehabilitation of a scheme employing two 300kW turbines and two 1.25MW turbines. The original turbines were produced by the French company Neyrpic, and rehabilitation has involved copying the original blades [Vo Sy Huynh, 1990].



FIGURE 4.19: A 200kW Francis runner being finished at the RERC, Hanoi

Mechanical Engineering Factory, Ho Chi Minh City

This factory on the outskirts of Ho Chi Minh City has been casting the casings for Francis turbines, under sub-contract from the Hydro Electric Research Centre, since 1990. So far three casings have been produced for turbines with capacities up to 200kW. The quality and strength of the casting seems to be good and no problems have yet been found with installed equipment.

They have previously attempted to fabricate Francis turbines, but the quality was very poor. As part of the Ministry of Heavy Industry, the organisation makes a wide variety of other mechanical products and has a casting works and substantial machine workshop facilities.

Research Centre for Thermal Research & Renewable Energy, Ho Chi Minh City

This centre, a part of the Polytechnic University of Ho Chi Minh City, has been manufacturing pumps and wind turbines for several years. They are eager to obtain a designs so that they can manufacture micro-hydropower turbines, but as yet have not done so. They do not yet have any experience in turbine manufacture.

Hydromec, Ho Chi Minh City

Under the direction of the Ministry of Hydraulic Resources, this organisation is involved in the manufacture of penstock and intake gates. They have been involved in a joint venture with a Chinese company working on a 3MW scheme at Dau Tieng, with the equipment coming from China, and are looking for further contact with foreign companies [Phan Khanh, 1992].

4.5.10. Test facilities

The Hanoi Polytechnic University has developed testing facilities which it uses to assess the Family-hydropower units produced by the RERC. It has two pumps capable jointly of delivering approximately $0.1 m^3/s$ to a header tank. The maximum head is approximately three metres and the maximum electrical output which can be measured is around 2kW. Light bulbs are used as loads; the flow rate is measured by a weir; and no advanced or accurate measuring equipment is available [UNIDO, 1988].

The Institute of Hydraulic Research of the Ministry of Water Resources have also designed and built their own test facilities consisting of a 75kW pump producing an equivalent maximum head of 25 metres and a maximum flow rate of 0.5 cubic metres per second [UNIDO, 1988].

The lack of a national standard laboratory test facility and the general shortage of measuring equipment has been a major draw-back to the development of new and efficient turbines. During the 1980's, none of the major producers of turbines were able to test the quality of their products, and still most manufacturers do not have access to test

facilities. The United Nations Development Programme (UNDP) attempted to initiate a project to establish a laboratory with the intention to test turbine designs and examine the efficiency of the equipment already in existence. It did not go ahead due to the internal politics of the situation and also the high cost of the project, being approximately US$1.4 million in 1986 [UNDP, 1986].

The Electric Equipment Manufacturing Plant, a part of the Ministry of Energy, have a relatively modern electrical test bench with equipment from the old USSR [Nguyen Khac Diem, 1992]. The Dong Anh Factory possess X-ray and ultra-sonic equipment capable of measuring material yield strength [UNIDO, 1988], but this facility is not available to other manufacturers.

4.5.11. Assessment of the local manufacturing capabilities

Vietnamese organisations have proved to be capable of producing Francis, Kaplan, crossflow, Pelton and propeller turbines and associated equipment in the range 200W to 2.1MW. However, many of the schemes using equipment produced in the 1980's by the Dong Anh Factory and Machine Tool Factory Number One, are now not working, leading to the situation whereby authorities have been reluctant to purchase Vietnamese equipment, preferring the often more expensive Chinese machines. The large number of organisations involved in the design and manufacture of equipment, and the lack of standardisation, have been pointed to by some experts [Cromwell, 1991; UNDP, 1986] as being the major reasons for the inadequacies of the turbines produced during the 1980's. Design and manufacture of plant by many different organisations resulted in large variations in standards and little accumulation of experience. Equipment presently being produced in the country is generally accepted to be of a much higher quality to that of the previous decade, with new companies such as the Hydro Electric Research Centre using the knowledge of some of the country's best experts in small-scale hydropower technology. It is anticipated that the equipment from these suppliers will become more popular as their improved quality becomes more widely known. Ultimately it is still thought to be cheaper to substitute equipment many times, than to buy higher quality and higher cost equipment from abroad [pc: Nguyen Duc Loc (c)]. For example, the turbine, governor, generator and control equipment for the rehabilitation of a 200kW scheme in disrepair is currently being replaced, after the original equipment from the Dong Anh factory proved to be inadequate. Vietnamese equipment will cost approximately US$70,000, whereas a Chinese provincial supplier quoted a price of US$125,000 for equivalent equipment, and that from Europe would be considerably higher.

As well as the poor performance of their equipment, another reason why the Machine Tool Factory No.1, and the Dong Anh Factory are no longer manufacturing, is due to changes in government financing. In the past, funds were available directly from central government for individual projects. Now, each local authority interested in developing a site must supply its own funds, which it will have to do in competition with other demands placed upon its resources. Thus hydropower projects have become less profitable, and the return on investment is lower than for other products which these large factories are capable of producing. Also, for the first time, each of the factories has become accountable for its own financing, as opposed to being subsidised by government as has been the case in the past, so although they are still obliged to manufacture equipment under orders from the government and local authorities, they have more possibilities to decide upon which products to manufacture and are able to focus upon those which reap the highest benefits for the company. Hydropower equipment has been shown to produce low profits.

Installation of reaction turbines at sites where the choice of turbine has not been properly matched to the site head has resulted in the rapid cavitation of many turbines. This, in combination with the lack of adequate de-silting civil works, has been the major cause for the breakdown of such a large percentage of installed equipment. Figure 4.20 shows the effects of cavitation on a runner taken from service in Vietnam. The Institute of Electrical Science and Technology are providing consultancy services to stations with cavitation and bearing problems [UNIDO, 1988], however, this is only likely to be cost effective at large or prestigious sites. Provisions for repair and maintenance are essential for the continued operation of schemes. However, shortage of spare parts and the lack of standardisation between pieces of equipment have compounded the maintenance problems [Dam Xuan Hiep, 1991].

There is still a lack of certain design capabilities and know-how, such as detailed information concerning how to obtain more efficient blade profiles for Kaplan and Francis turbines, and also information about low cost governor technology such as ELCs. This lack of information available to researchers, engineers and technicians in Vietnam is seen as being one of the greatest obstacles to development of renewable energy technologies in the country [Nguyen Van Than, 1991] and has been partly caused by the isolation of the country. The lack of an adequate test laboratory has also restrained improvements in turbine and equipment design.

Low cost, and designs for low-head equipment, are important factors in the sale of Family-hydropower equipment to the lowland, more prosperous market in Vietnam [SHP

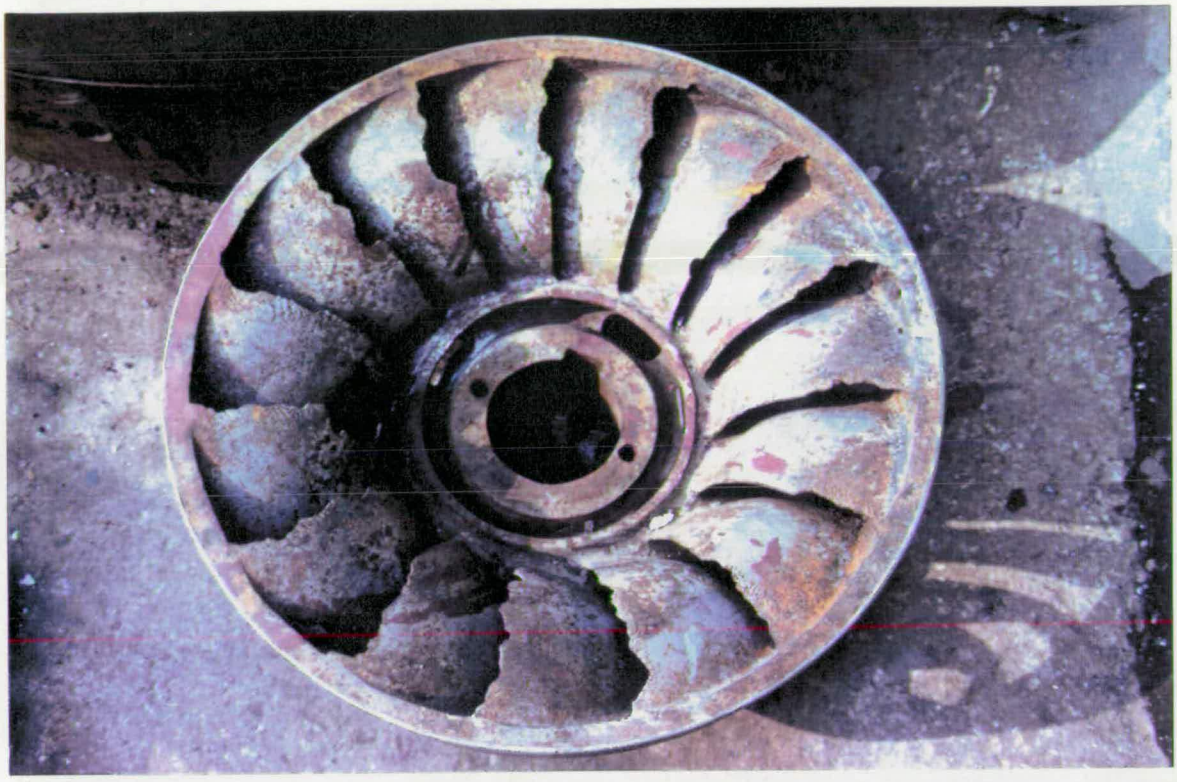


FIGURE 4.20: A turbine runner removed from service in Vietnam due to excessive cavitation

News, 1992]. Currently their appears to be no enthusiasm to buy Family-hydropower equipment from the manufacturers in Hanoi, as the Chinese turbines come in a wide range of products, are cheaper and are of a proven design [Cromwell, 1991].

4.5.12. Requirements for local manufacture

New policies to promote Vietnamese manufacturer's equipment should focus in particular on the improvements in quality of the turbines now being produced and their low cost.

A definite policy is required to secure a reliable supply of equipment and spares either from local organisations, or from China. Also a more constant policy on subsidies for the Family-hydropower units will stabilise the market.

One of the main priorities is to develop a cheap form of governing for schemes with capacities below 100kW. Although the electronics capabilities in the country are low, ELCs should still prove to be cost effective.

The ability to test prototypes and the necessity of quality control of the final products will require the acquisition of both test equipment and measurement equipment. The country would also benefit from a test facility for turbines.

There is a need for the improvement of de-silting methods for small-scale hydropower sites. There is also the need to develop the capabilities of blade protection for the larger schemes, however, the cost of this will probably be prohibitively high for the smaller schemes.

Other technology transfer which is required includes the following.

- The acquisition of a high efficiency Kaplan turbine profile. They have in the past copied equipment from other countries and adapted the blade profile.

- Transfer of equipment and the necessary skills to mass-produce generators in order to reduce their cost. It is presently considerably cheaper to purchase the generators from China, or use the generators from old diesel sets.

4.6. CHAPTER SUMMARY

Over 400 small-scale hydropower schemes have been established in Vietnam, however, half of the sites built in the country are now not in operation. This has mainly been due to the lack of provision for financial security to pay for project repair and a lack of adequate maintenance. The US economic embargo of the country has prevented the government from obtaining funds from most foreign sources, but with restrictions recently having been lifted, new trade agreements will soon become available enabled by the inflow of funds. There are many well trained engineers in the country, and the majority of sites have been constructed without direct foreign assistance. The failure of such a large proportion of sites has also been caused by the inappropriate choice of reaction turbines at many sites, compounded by the poor quality of the turbines produced during the 1980's, by the high silt content of many of the country's rivers and the inadequate de-silting designs to cope with this.

Turbine designs were initially obtained by copying Chinese, and other countries' equipment. Vietnam presently has design and manufacturing capabilities for turbines ranging from 200W to 2.1MW, with Francis, Kaplan, crossflow, Pelton and propeller turbines having been produced. All other equipment required for a small-scale hydropower project has also been produced in the country, however, the availability of

disused diesel generators has allowed their use as the main source of generators. There has been a wide diversity of equipment, and no standardisation of design between companies has so far been attempted. This has made it very difficult to hold adequate stocks of spare parts. The inadequacies of much of the equipment produced in the 1980's has created a poor reputation for Vietnamese equipment, and there is presently little enthusiasm to purchase home made turbines, whereas Chinese equipment is proven and reliable, although more expensive. With the low cost of reliable and efficient Vietnamese equipment which is now available, the demand for locally produced mini- and micro-hydropower equipment is likely to rise again.

There are several perceived technology transfer requirements including:

a) obtaining improved Kaplan and Francis turbine profiles;

b) developing a cost effective governor for schemes below 100kW;

c) creating a test and measurement facility, for testing prototypes, and assessing the quality of manufactured equipment.

Family-hydropower units have become popular due to their low cost, ease of installation and light weight. So far around 3,000 units have been installed, the majority originating from China. Vietnamese designs are not as popular as they are more expensive, however, they have been proven to be more efficient and reliable. With an average annual income of a typical Vietnamese farmer being between US$150 and US$200, low capital cost will remain the overriding factor affecting small-scale hydropower development in the country.

CHAPTER FIVE: COUNTRY STUDY - THE LAO PDR

5.1. COUNTRY PROFILE

The Lao People's Democratic Republic (PDR) is a land locked country with an area of 236,800 square kilometres, stretching over 1,000km in length [Sumphorn Manodham, 1992]. Approximately 80% of the country lies in hilly or mountainous areas [Pho Muangnalad, 1991], and much of the country is characterised by deep valleys and fast flowing rivers in the wet season. The climate in tropical to sub-tropical, and approximately half of the country is covered by dense tropical forest [Sumphorn Manodham, 1992].

In 1990, the population was estimated to be 4.17 million, 85% of whom live in rural areas, scattered amongst 11,000 villages, between which there can often be 20 to 30km [Sumphorn Manodham, 1992]. A large percentage of the rural population live at a subsistence level, relying upon slash and burn agriculture for their livelihoods [Phalasack Pheddara, 1992 (b)], and agriculture, including forestry, accounts for two thirds of the country's Gross Domestic Product (GDP), employing around 80% of the labour force [Saetersmoen, 1992].

The Lao economy has until recently been centrally planned, with the government having ownership and control over virtually all manufacturing enterprises [UN, 1990 (b)]. Recent restructuring of the economy with the introduction of the New Economic Management System has led to the decentralising of this control and the encouragement of private enterprises [Government of Lao PDR, 1989]. This has amounted to a complete overhaul of the economy, which has resulted in inflation falling from 76% in 1989, to around 10% in 1991. Foreign aid grants play a major part in the country's economy, and in 1991 they were nearly twice as much as the country's total export earnings [Hiebert, 1992].

Intra-regional trade is becoming ever more important as trading policies become more liberal, and as aid from the former Soviet Union and Eastern Europe has been cut sharply. The Lao PDR has had a special relationship with Vietnam since they both gained independence, and recently the Lao government has also been seeking to improve relations both with China and Thailand [Hiebert, 1992 (b)]. The first bridge across the Mekong, linking northern Thailand to the Lao PDR's capital, Vientiane, demonstrates this new relationship between the two countries and will most probably help strengthen ties

and increase trade in the region. The country's major exports in 1991 were forestry products (US$33 million) and electricity sales to Thailand (US$17 millon) [Hiebert, 1992 (a)], followed by sales of green coffee and tin [ADB, 1991].

The country's industrial sector is very small, and government investment into industry has been low, and restricted to only a few state enterprises. In 1990, industry contributed only approximately 14% to GDP [UN, 1992 (b)], and until recently it was typically crippled by inefficiency, outdated equipment, a lack of materials and a shortage of foreign exchange [Government of Lao PDR, 1989]. The average per capita income of approximately US$220 is very low by international standards, and the relatively small population of the Lao PDR limits the size of the market for products, restricting the benefits which would otherwise accrue from economies of scale [UN, 1990 (b)]. The country is also limited by financial and labour shortages at its governmental institutions, inadequacies of its road networks leading to high transportation costs [UN, 1990 (b)], poor communication infrastructure, the small percentage of the population who are technically trained, and a lack of investment, all of which restrict the country's socio-economic development. The problems to be faced due to the lack of infrastructure are highlighted by the situation faced during the development of a 45MW hydropower scheme in the South of the country, when in order to transport the necessary equipment to the site, twenty bridges had to be reinforced.

5.2. ENERGY SITUATION

5.2.1. Energy supply and demand

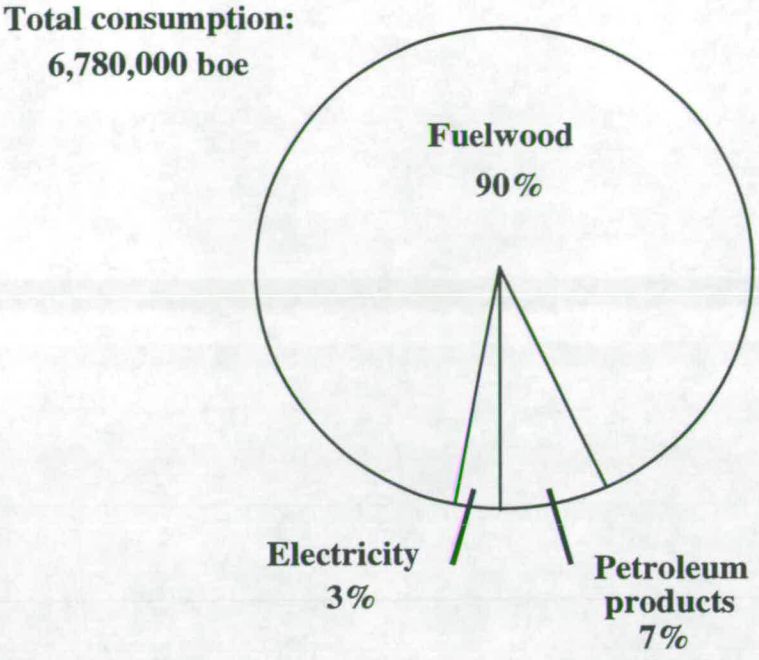
The Lao PDR has large coal reserves, substantial forestry resources and vast hydropower potential [Government of Lao PDR, 1989], most of which have so far not been exploited. The country's energy consumption pattern is dominated by the use of fuelwood, which accounts for 90% of all the energy consumed, whereas petroleum products account for 7% and hydropower generated electricity 3% [ECIU, 1993], as shown in Figure 5.2. Commercial energy consumption showed a rapid growth during 1988 and 1989, following the country's change to a market orientated economy [UN, 1992 (b)].

Fuelwood is predominantly used for cooking in rural areas, and charcoal is also used both in rural and urban areas [Pho Muangnalad, 1991]. Fuelwood accounted for approximately 98% of the total household energy consumption in 1990, with a per capita consumption rate of approximately one cubic metre per year [UN, 1992 (b)]. With an annual rate of increase in the population of around 2.9% [Phalasack Pheddara, 1992 (b)]



[Source: Nelles Verlag]

FIGURE 5.1: Relief map of the Lao PDR



[Source: UN, 1992 (b)]

FIGURE 5.2: Total energy consumption by fuel type (1990) in the Lao PDR

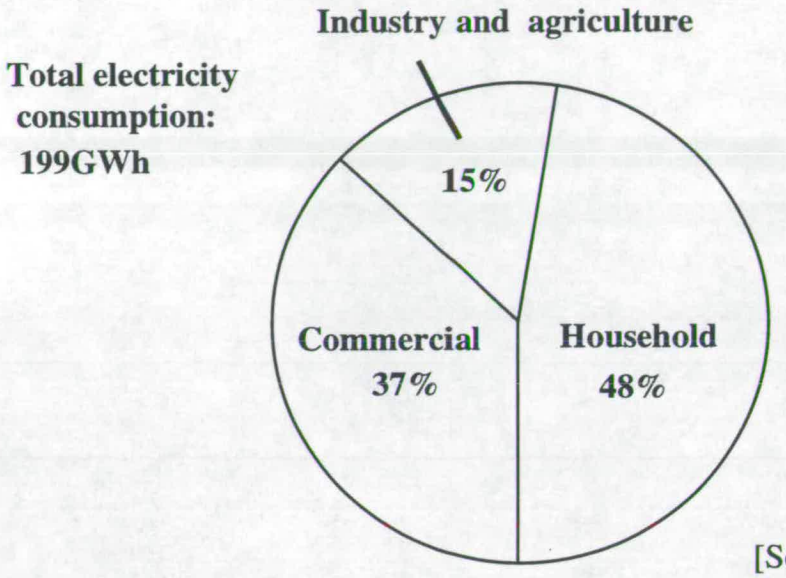
and increases in per capita usage, the consumption of fuelwood is estimated to increase by more than fifteen million cubic metres per year to over twenty million cubic metres per year by the year 2000, unless suitable substitutes are found [UN]. Forest has been damaged by both logging and shifting cultivation, as well as by fire [Pho Muangnalad, 1991], and although the export of logs was banned in 1990 to conserve the forest, this has been ignored in many areas [Economist, 1992]. Some hydropower projects have attempted to reduce the use of fuelwood by providing a substitute, but the majority of the electricity produced has been for export to Thailand. Plans for the development of a scheme on the Nam Theun have been scaled down to allow for timber activities in the region [WPDC, 1992 (a)], which may inadvertently affect the feasibility and life span of the scheme due to added siltation problems from the logging operations.

All petroleum products are imported, which in 1990 amounted to 118,000 tons, and are used mainly for the transport sector [UN, 1992 (b)]. In addition, kerosene is used for lighting in may areas.

5.2.2. Electricity supply and demand

The Lao PDR has one of the lowest per capita electricity generation figures in the world, at 201kWh/year (1990), of which over 70% is exported to Thailand [UN, 1992 (b)]. This results in an average electricity consumption per household of 135kWh/year (1990) for the country as a whole [UN, 1992 (b)]. Approximately 13% of the households in the

country have access to electricity, which represents 90,000 households. Only 10% of the electricity is used for industry, or family handicrafts [ECIU, 1993], whereas approximately 20% of the electricity consumed is for lighting, and 23% for cooking.



[Source: UN, 1992 (b)]

FIGURE 5.3: Electricity consumption by sector (1990) in the Lao PDR

Figure 5.3 shows the electricity consumption figures by sector [UN, 1992 (b)]. Of the electricity consumed within the country, Vientiane accounted for 85% of the total in 1986 [Government of Lao PDR, 1989], having 55% of the electrified households, although being home to just 18% of the country's population.

	Electrical energy (GWh)
Production	839
Consumption	199
Import	26
Export	595

[Source: UN,1992 (b)]

FIGURE 5.4: Electricity production, consumption, import and export in 1990

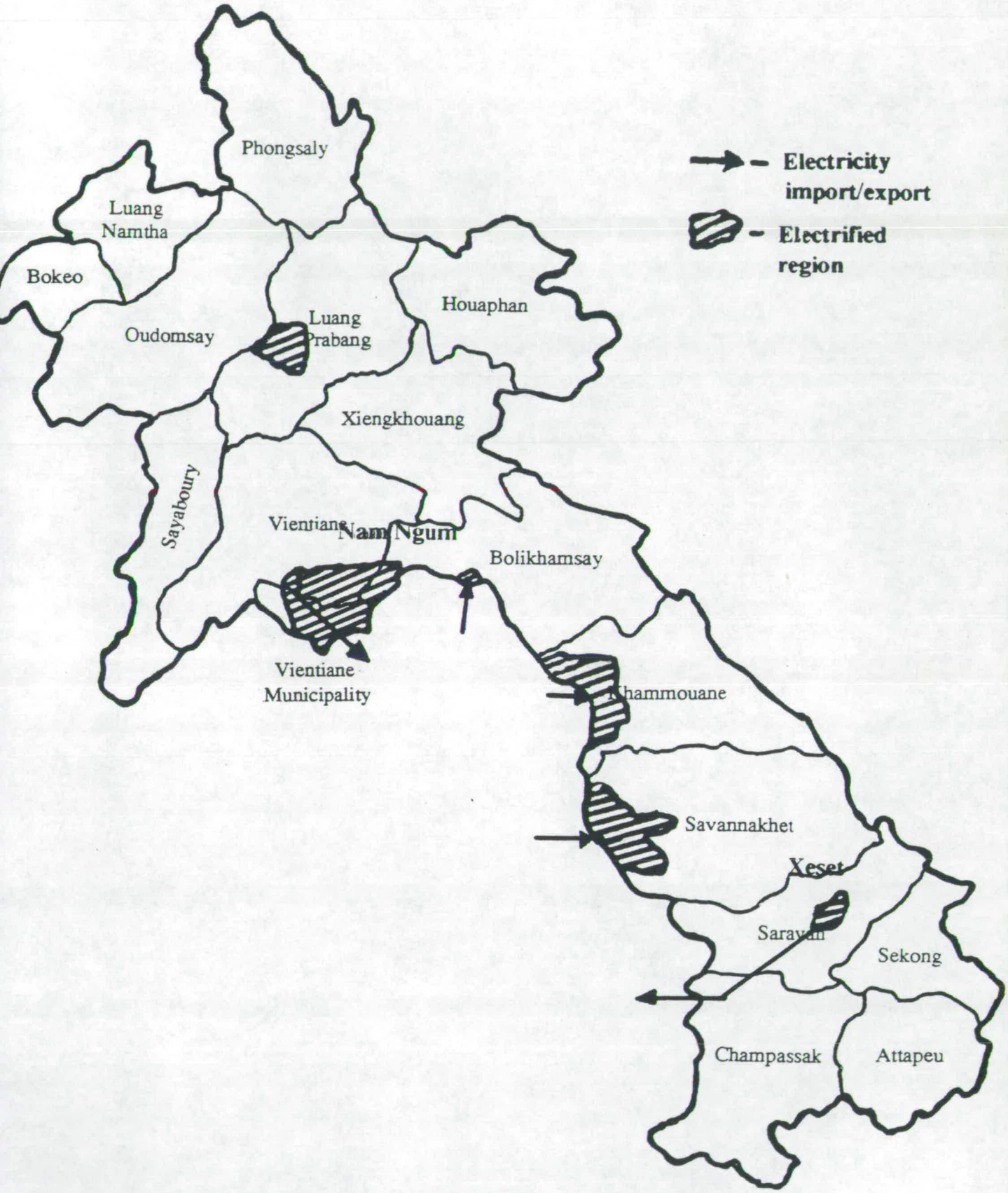
Figure 5.4 shows the electricity production, consumption, import and export figures for the country in 1990 [UN, 1992 (b)]. In 1991, the total amount of electricity generated

was 961 GWh, 99.7% of which was from hydropower. Of the total installed capacity, which is in the order of 211MW, approximately 200MW is hydro and the rest diesel [Houmphone Boulignaphonh, 1992]. The annual increase in demand for electricity capacity is approximately 5 MW [Oud, 1993].

There is no national grid, however, as well as two medium size hydropower stations there are fourteen diesel groups and several small-scale hydropower stations [ECIU, 1993]. Few provinces have distribution networks outside of the provincial town (see figure 5.5) [UN, 1992 (b)], and very few provinces have interlinking local grids. The provinces of Savannakhet, Borikamsay and Khammouane import electricity from Thailand via 22kV lines, with the Savannakhet line possibly being upgraded to 115kV in the near future [EGAT, 1991]. Champassak has a small 2MW hydropower station at Xelabam, and the Xeset 45MW hydropower scheme supplies electricity to parts of Champassak and Saravan provinces [UN, 1992 (b)]. The Xeset scheme is also connected to the Thai system, allowing for exports of electricity during the wet season, and some import during the dry season, when the generation capability of the scheme sometimes falls to as low as 3MW [Sumphorn Manodham, 1992].

The Vientiane grid is the largest in the country, serving approximately 60,000 customers and having a peak demand of 40MW [Oud, 1993]. This grid receives power mainly from the Nam Ngum 150MW hydropower scheme which primarily exports electricity to Thailand. There is already an over-capacity in the Vientiane area and future schemes constructed in the region will be built primarily in order to export electricity. The Nam Ngum scheme is also soon to be connected to the country's second major town of Luang Prabang via a 115kV transmission line. Until now Luang Prabang has relied upon the 1MW Nam Dong hydropower station, commissioned in 1971, and a 700kW diesel station [Houmphone Boulignaphonh, 1992], both of which are experiencing efficiency and reliability problems.

Attapeu and Sekong, like most other provinces, have diesel generators for use predominantly in the provincial capital [UN, 1992 (b)], and often for only a few hours of the day [Houmphone Boulignaphonh, 1992]. In Sayaboury, three diesel units generate approximately 11,500kWh per month, consuming 3,600 litres of fuel, and providing electricity only between 6pm and 9pm due to fuel shortages [Government of Lao PDR, 1989]. Grid connection to the provinces of Houei Sai, Oudomsay, Phongsaly and Houaphanh in the North of the country is not expected, due to their remoteness, and diesel shortages limit the electricity generation in these areas [Houmphone Boulignaphonh, 1992]. In all of the other provinces some privately owned diesel



[Source: Pho Muangnalad, 1991]

FIGURE 5.5: Provincial map of the Lao PDR showing rural electrification coverage

generators are in operation, mainly in villages to be found along the major roads, and some isolated villages have micro-hydropower schemes (see section 5.4). Three biogas schemes were initiated in the country, but they were not considered to be successful and are no longer operating [UN]. Very few wind powered machines have been used, and solar photovoltaics are presently only being considered for telecommunications projects [Pho Muangnalad, 1991].

Tariffs for electricity are not uniform across the country, as can be seen from figure 5.6. Electricity in the Lao PDR is sold for between 8 Kip/kWh (US$0.011/kWh) for the first 100kWh of distributed electricity for household use in Vientiane, to over 1,000 Kip/kWh (US$1.39/kWh) in some areas for a battery-powered low wattage bulb used for a few hours per night [pc: Preston]. In remote areas, a flat rate of 800 - 1,000 Kip/month is often charged for a 40W bulb, equivalent to approximately US$0.31 - US$0.39/kWh for the average usage of 3 hours per night [Sumphorn Manodham, 1992]. In Sayaboury province, as there are no meters to measure household consumption, electricity is sold by the local generation board at 10 Kip/watt/month of the capacity of users' appliances [Government of Lao PDR, 1989]. This works out to be 400 Kip/month (US$0.56/month) for a 40W bulb, contrasting to a cost of 29 Kip/month (US$0.04/month) for the equivalent in Vientiane used for three hours per night.

Province	Price		Conditions of use
	Kip	US cent	
Vientiane	7	1.0	Monthly consumption < 300kWh
	14	2.0	Monthly consumption > 300kWh
	7	1.0	Agriculture
	9 - 11	1.3 - 1.6	Industry
Savannakhet	17 - 18	2.4 - 2.5	
Luang Prabang	48	6.7	
Champassak	14	2.0	
Khammouane	18 - 19	2.5 - 2.6	
Saravan	19	2.6	
Others			Based on usage and losses

[Sources: UN, 1992 (b); Sumphorn Manodham 1992]

FIGURE 5.6: Electricity prices for local consumers in the Lao PDR, 1990

The tariff for domestic consumption of electricity which is charged by Elèctricité du Laos (EDL) does not meet the production costs [UN, 1990 (b)], and EDL, which has received

low interest loans from the Asian Development Bank (ADB) and the World Bank, is being pressured into increasing tariffs [Sumphorn Manodham, 1992].

Many villages along the country's major roads have a diesel generator, most often having been set up for battery charging, and often assembled from disused components. For example, between Pakse and Saravan in the South of the country, a bank of batteries may be charged from a 24V diesel generator, for the price of 500 Kip (US$0.70) for a 70Ah battery, and 100 Kip (US$0.14) for a 3Ah battery [pc: Pakse]. These 3Ah batteries can be purchased for around 3,800 Kip (US$5.32).

5.3. RURAL ELECTRIFICATION

5.3.1. History of rural electrification

The first rural electrification programme in the country, which focussed upon the Vientiane Plain, was completed in 1986. It linked 2,400 households and supplied electricity for pump irrigation schemes in the plain region. In the second phase, a further 5,284 rural households were connected via 219km of 22kV line, and 289km of 400V a.c. distribution line [Sumphorn Manodham, 1992]. In the past few years other rural electrification programmes have been embarked upon, as will be described in section 5.3.4.

The benefits considered to have been gained from the Vientiane Plain rural electrification programmes, include [Sumphorn Manodham, 1992]:

- an increase in agricultural production by about 45,000 tons, representing a 63% increase for this area;
- development of agricultural processing and other small industries;
- the lengthening of working hours by the provision of light;
- a greater number of people with access to media via TV and radio;
- an improvement in health facilities via the provision for the refrigeration of vaccines, and by sterilisation;

- an improvement in the education facilities for rural students.

It should be noted, however, that the most predominant end use is lighting [Sumphorn Manodham, 1992], with productive end uses accounting for no more than 10% of consumption.

5.3.2. Government policy towards rural electrification

The government has not produced a master plan for rural electrification, though provincial capitals, followed by district headquarters, have been the first to receive electricity, usually in the form of a small diesel generator. The major constraints on the expansion of of the rural electrification network is the lack of investment funds, and most of the rural electrification programmes have been funded by international grants and loans. The provincial government offices are in receipt of government funding which they can spend as they feel fit, but these have been inadequate to finance large rural electrification projects. It is feasible, however, that they could be used to part-fund micro-hydropower projects [pc: Narongsack Sayakounh].

Due to the lack of hard currency the government is hoping to construct several medium sized hydropower schemes in order to export electricity to Thailand. These projects may lead to the electrification of some surrounding rural areas. The government's stated objectives for any rural electrification developments are, in order of priority [Sumphorn Manodham, 1992]:

- to increase food production;
- to develop agricultural based and other industries;
- to provide lighting to rural people;
- to stimulate productive activities.

5.3.3. Rural electrification agencies

All major generation and distribution systems within the Lao PDR are owned and operated by EDL, who also control all imports and exports of electricity with Thailand [UN, 1992 (b)]. They are also responsible for planning, feasibility studies and development of rural electrification programmes [Sumphorn Manodham, 1992]. Other

organisations concerned with rural electrification via their involvement in micro-hydropower developments are:

- the Institute of Irrigation and Micro-hydropower, of the Ministry of Agriculture and Forestry, and;

- the Micro-hydropower Department, of the Electrical Construction and Installation Section, the Ministry of Industry and Handicrafts.

Both organisations usually work in conjunction with foreign organisations establishing small-scale hydropower schemes in the country, and they have very little expertise in constructing, or designing schemes.

5.3.4. Extent of rural electrification

The Lao PDR has one of the lowest consumption rates of electricity in the world [Pho Muangnalad, 1991]. Whereas 7.2% of villages were electrified by 1990, only 1.6% of the rural population had access to electricity [Sumphorn Manodham, 1992].

Since the development of the Vientiane Plain rural electrification programme, expansion has been very slow. Most of the country's major provincial towns have some supply of electricity as described in section 5.2.2, but other than on the Vientiane Plain, the extension of the grid outside of these towns has only taken place to very few villages. With the lowest population density in South-East Asia, many villages are relatively remote and thus the cost of extending local electrical grid lines is excessively high [Sumphorn Manodham, 1992]. A small number of diesel and micro-hydropower schemes have been set up in the hilly and mountainous regions to the North and East of the country, where extension of the grid is not economically feasible. Most of these hydropower and diesel sets are in a poor state of repair, and many only operate at a fraction of their nominal capacity [Sumphorn Manodham, 1992]. In most highland areas their use is hampered by high fuel costs, and by fuel shortages, due to problems brought about by transportation in adverse weather conditions and the difficult terrain [Sumphorn Manodham, 1992]. There is only one North-to-South highway system in the country.

Approximately 70 villages, all within 2km of the main road, are in the process of receiving electricity from the Xeset hydropower scheme in the South of the country [pc: Narongsack Sayakounh]. The Southern Area Electrification Project is expanding the grid in parts of the provinces of Saravan, Champassak, Sekong and Attapeu, using power from

the upgraded Xelabam hydropower project and the Xeset project. Other distribution network extensions being undertaken are [Sumphorn Manodham, 1992]:

- Khammouane - 600 households being connected by 40km of distribution line;
- Savannakhet - 3,100 households will be connected;
- Champassak - a further 3,900 households to be connected via 186km of 22kV line and 144km of low voltage network.

As part of the programme to connection the Nam Ngum hydropower project to the provincial capital of Luang Prabang extension of the grid will be made to the rural districts of Vang Vieng, Kasi and districts around Luang Prabang, with the possibility of the network being extended to Sayaboury and Xieng Khouang provinces [Sumphorn Manodham, 1992].

Very few surveys of electricity demand have been undertaken in the provincial towns and villages. For most areas lighting would be the predominant use, the source for which is presently predominantly kerosene and in some areas electricity from rechargeable batteries.

With the current tariff levels, EDL is not able to generate income in order to develop and expand the rural electrification network, and must borrow or obtain foreign funds. Lack of staff resources also limit distribution expansion. There has been local participation in the construction of some of the rural electrification schemes, in the form of contributions of wooden poles, cutting of trees for pole installation and the provision of labour [Sumphorn Manodham, 1992].

5.4. HYDROPOWER IN THE LAO PDR

5.4.1. Introduction

Historically waterpower has been harnessed for productive use in the hill areas of the Lao PDR for hundreds of years. Large water wheels have also been used traditionally in order to raise water for irrigation purposes, and wooden pounding devices for de-hushing rice.

No area of the country receives less than 1,000mm of rainfall per year, whereas the average is 1,800mm per year. Approximately eighty percent of the country is covered by

mountain and plateau regions [Sumphorn Manodham, 1992].

The first hydropower scheme in the country, the 150MW Nam Ngum project, came into operation in 1971 when the first of its turbines were commissioned. Hydropower has been developed primarily in order to gain foreign exchange and reduce dependency on fuel imports, by earning hard currency from sales of electricity to Thailand [Saetersmoen, 1992]. A number of smaller micro-hydropower schemes have been developed, principally with funding from NGOs, for local use in remote areas.

The total hydropower potential within the country and along its borders is in the order of 20,000 MW [Oud, 1993]. Surveys are being undertaken for several projects throughout the country, including on the Nam Theun, Nam Leuk, Nam Song, Nam Ngiap, Nam Ngum, and Sekatam rivers [Sounthone, 1992]. Asian Development Bank (ADB) funds of US$1.3 million have been approved for a feasibility study of the Nam Song and Nam Leuk rivers, the diversions of which to the Nam Ngum reservoir could generate a further 27GWh/year and 104GWh/year respectively [WPDC, 1992 (c)]. Plans for the 600MW Nam Theun, may be scaled down to 120-240MW in order to allow for timber activities in the region. The electricity from each of these schemes will primarily be for export to Thailand.

5.4.2. Hydropower institutions

Large hydropower developments are under the auspices of Electricite du Laos at the Ministry of Industry and Handicrafts [pc: Viraphanh Nandavong]. An independent organisation, Hydropower Engineering Consultants, are involved in the development of medium and large projects, and they have acted as counterparts to overseas consulting firms. They are capable of project planning for all types of hydropower schemes, as well as project supervision, including equipment installation [Adachi, 1992].

Micro-hydropower development is the responsibility of both the Department of Irrigation and Micro-hydropower of the Ministry of Agriculture and Forestry, and the Department of Micro-hydropower of the Ministry of Industry and Handicrafts. They have been involved in the supervision of projects funded by NGOs and other international organisations, but do not have enough experience to install a scheme independently. The micro-hydropower department of the Ministry of Industry and Handicrafts are presently involved in the installation of a 90kW scheme in Sayaboury Province. The Ministry of Agriculture and Forestry's Institute for Irrigation and Micro-hydropower is mainly concerned with irrigation projects, but is requesting funding for three micro-hydropower

projects.

5.4.3. Micro-hydropower

The high levels of rainfall, the terrain and the dispersed population are favourable for small-scale hydropower developments for rural electrification. Over twenty micro-hydropower schemes have been initiated throughout the country, however, many are thought to be out of operation, or running at a low output [Inversin, 1991 (b)]. Figure 5.7 provides details of most of these micro-hydropower sites, and all of the larger hydropower stations. There have been at least six other micro-hydropower schemes and an unknown number of Family-hydropower units installed.

Many sites have been allowed to fall into disrepair, due to inadequate maintenance and repair. Lack of technical knowledge available within the country has led to the demise of many schemes. In some cases repair has not even been attempted, primarily due to the lack of expertise locally available, and to the cost of acquiring capable engineers, increased by the difficulties involved with transport throughout the country. This lack of infrastructure and well trained staff is a typical scenario for developing countries attempting to develop their rural electrification network [Randell, 1992; Whittaker, 1988]. As well as lack of investment capital to initiate the schemes, financial considerations beyond construction are often also inadequate. Promotion of productive end usage is seldom undertaken, and very little thought is given to anything beyond the construction phase [Inversin, 1991 (b)]. At many of the schemes demand for electricity is a fraction of the installed capacity, and tariffs are often set low in order that the electricity is affordable to the recipients, resulting in revenue often being below operation and maintenance costs [Inversin, 1991 (b)]. Also, money is seldom saved for when a major overhaul is required, and thus several schemes have been left idle after a few years of operation.

Many villagers have experience with harnessing water power in the form of mechanical rice husking devices, but lack of expertise with respect to micro-hydropower schemes is one of the main factors limiting their development within the country. The lack of design knowledge is highlighted by a site implemented by EDL in Luang Prabang. Two micro-hydropower units have been installed in the village, the first being used solely for a belt driven rice mill, the second connected to a 5kW generator to supply electricity for the village of approximately 70 households. Originally the scheme was designed for 10kW, but the penstock had a diameter effective for a 2.5kW site [Inversin, 1991 (a)], and thus each household was restricted to having a single 25 or 40W light bulb. This scheme recently broke down due to problems with the main bearing, and without adequate

No.	Station	Province	Power (kW)	Head (m)	Flow Rate (m^3/s)	No. of turbines	Type	Made in	Funded by
1	Huai Samong	Attapeu	200	15	2.00	2	CF	G	V
2	Xesabam	Champassak	2,040	15	15.00	3	KA	F	F
3	Huai Nam Sai	Champassak	20	8	0.34	1	CF	N	US
4	Huai Lu Si	Champassak	10	3	0.50	1	PR	V	V
5	Huai Champi	Champassak	68	9	0.78	2	CF	P	G
6	Thang Baeng	Champassak	9	5		1	CF	N	NGO
7	M. Paksong	Champassak	40	11		1	CF	G	
8	Nameo	Houaphan	40	3	1.80	1	PR	V	V
9	Naveed	Houaphan	5	3	0.30	1	CF	L	L
10	Nam Main	Houaphan	50	12	0.56	1	CF	V	V
11	Nam Et	Houaphan	126	7	2.20	2	CF	G	C
12	Sam Neua	Houaphan	20					V	
13	Nam Lu	Luang Namtha	46	6	1.00	1	CF	G	V & L
14	Nam Dong	Luang Prabang	1,200	137	0.90	3	PE	F	F
15	BanTha Paen	Luang Prabang	11	25		1	CF	N	NGO
16	BanTha Paen	Luang Prabang	3			1	CF	L	L
17	Ban Na Deuay	Luang Prabang	<10			1	TU	V	L
18	Nam Ko Noi	Oudomsay	10	3	0.45	1	PR	V	V
19	Nam Baeng	Oudomsay	6	4	0.22	1	TU	C	C
20	Huai Lay-2	Oudomsay	40	15	0.20	1	FR	C	C
21	Nam Bun	Phongsaly	50	3	2.12	2	PR	C	C
22	Xeset	Saravan	45,000	157	33.00	5	FR	S	T & L
23	Huai Ngoung	Saravan	30	8	0.54	1	CF	V	V
24	Ban Thateng	Saravan	<1			1	CF	L	L
25	Nam Ham	Sayaboury	150	15	1.50	2	CF	G	L
26	Bo Taen	Sayaboury	80			2			
27	Ban Cafe	Sekong	100			1	PE		
28	Nam Ngum	Vientiane	150,000	51	363.75	5	FR	J & G	J
29	Muang Tohia	Vientiane	5	3					
30	Nam Poui	Xiengkhouang	14	9	0.23	1	CF	V	V
31	Nam Ko	Xiengkhouang	4	5	0.12	1	FR	V	V

CF - Crossflow PE - Pelton C - China L - Lao PDR T - Thailand

FR - Francis PR - Propeller F - France N - Nepal V - Vietnam

KA - Kaplan TU - Tubular G - Germany P - Poland

J - Japan S - Sweden

[Sources: Phalasack Pheddara, 1992 (b); Leyland Consultants, 1988; Inversin, 1991 (a)]

FIGURE 5.7: Installed hydropower schemes in the Lao PDR

financial resources, or local repair capabilities to replace the bearing, the scheme is to be dismantled. The rice mill, however, is mainly only operated throughout the day, whereas during the evening, when electric power is in greatest demand, it is left idle. The demand for electricity already exists, and indeed many of the households have a distribution connection. The cost of installing a generator would be comparatively low, but without the knowledge or backup resources available, the villagers are without electricity.

One of the main problems for micro-hydropower developments is the high quantity of silt present in the water. It appears that few civil work designs have adequately taken this into consideration. The turbine fabricated at the Agricultural Tools Making Factory broke after three years of operation, principally due to erosion, and although the site is now being replaced with Ossburger equipment, the designer of the scheme expects that this equipment will follow the same fate [pc: Viraphanh Nandavong].

The majority of schemes have been funded, on a one-off basis, with aid from foreign governments or NGOs. Money has not been available from central government for micro-hydropower projects, unless the majority of funding for the powerhouse equipment is provided from abroad, in which case often the civil works are paid for by the Lao government. The Institute of Irrigation and Micro-hydropower, as well as other ministerial groups are eager to get involved with any project, but they have little experience [pc: Inversin (b)]. With no coordinated approach between the NGOs, the development of micro-hydropower schemes has been erratic and piece-meal. The demonstration and pilot projects have not enhanced the prospects of a sustainable nationwide programme, and have done little to increase the knowledge base in the country. Projects are often over-engineered, and due to their one-off nature they are relatively expensive, as there has been no possibility of economies of scale being reached. Nearly all have been reliant upon expensive foreign expertise, and thus a distorted view of the costs involved has been given to the Lao organisations capable of funding a micro-hydropower programme.

The Mennonite Central Committee, an NGO with offices in the Lao PDR, has developed two schemes with the intention to use these as demonstration projects to promote the proliferation of micro-hydropower technology throughout the country. They brought in a foreign expert from the United States of America for one year, and imported crossflow equipment from Nepal. The schemes of 9kW, and 11kW, having heads of 5.4m and 25m respectively [Leyland Consultants, 1988], are both working well after four years of operation. The schemes were primarily established for rice milling by direct drive (see figure 5.8), but in one case a generator has been attached, in order to charge batteries for

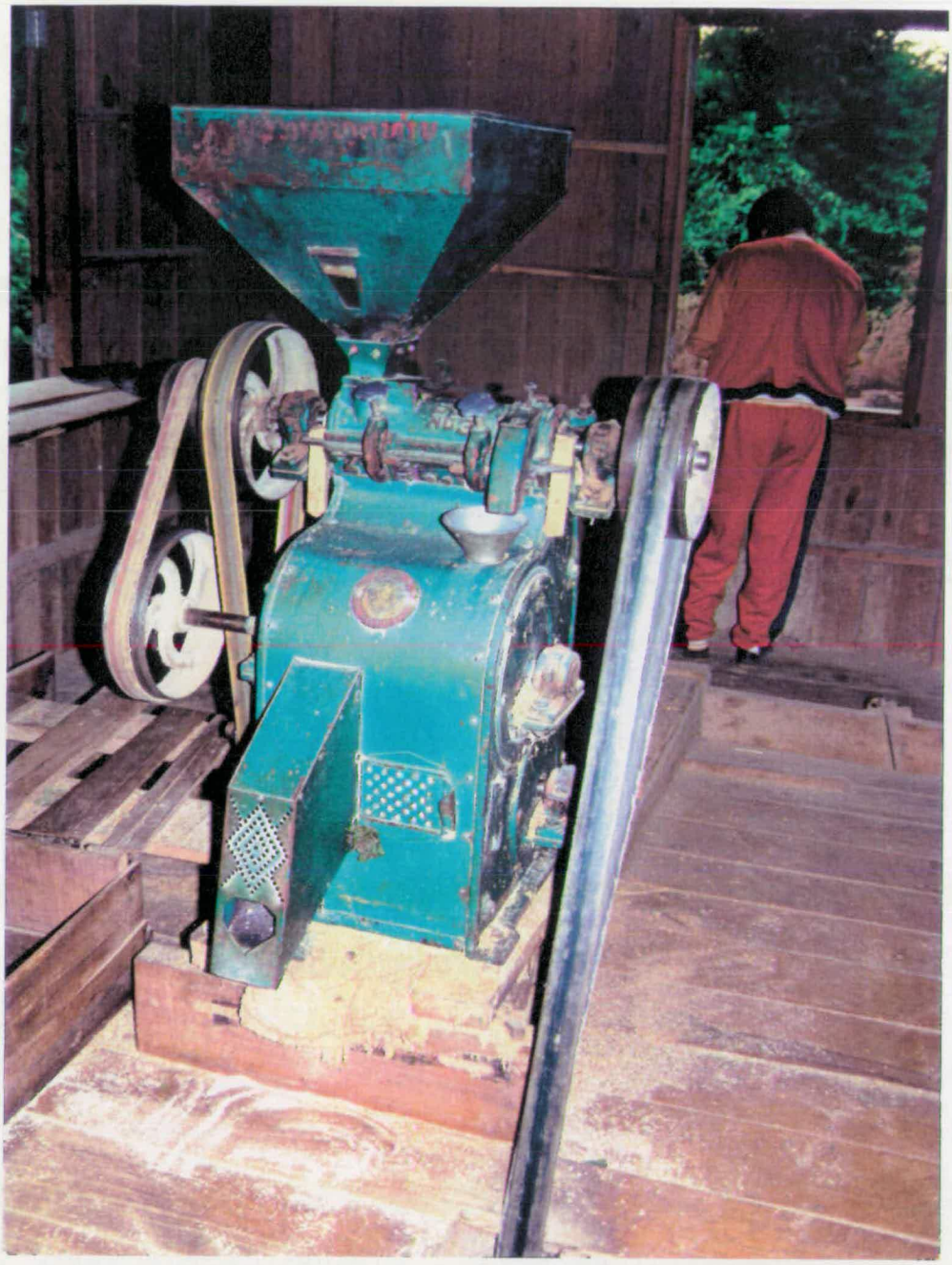


FIGURE 5.8: A rice mill being driven directly from a micro-hydropower unit at Houay Nam Si, Champassak province

the local villagers. With a 2kW generator and battery charger, 20 to 50 batteries are charged per day, at a cost of 100 kip for a motorcycle battery, and 400 kip for a car battery, netting an annual return of up to 1.5 million Kip (US$2,100) [pc: Lam Ngeunh Phakaysone (b)]. At the other scheme, revenue from rice milling is sufficient to pay for the operator, and the remaining two thirds of the revenue is donated to village funds.

5.4.4. Family-hydropower

In some areas of the country, individual families have installed Chinese-made Family-hydropower units for private use [Phalasack Pheddara, 1992 (b)]. These can reportedly be bought in the market place [Cromwell, 1991], particularly near to the Chinese and Vietnamese borders. Figure 5.9 shows the cost of some of the units on sale, though it is considered that the lower capacity equipment can be bought for a lower price than that quoted here. People in the hilly areas are seldom able to afford these prices, and thus use has so far been limited.

Capacity (W)	Head (m)	Flow rate (l/s)	Cost	
			kip	US$
100	1.2	20	97,500	135
300	1.5	30	115,700	161
600	2.0	40	163,800	228
1,000	3.0	50 - 100	208,000	289

[Source: pc: Viraphanh Nandavong]

FIGURE 5.9: Cost of Family-hydropower units in northern Lao PDR

5.4.5. Future plans

In most provinces no assessments have been made of the demand for, or potential for, small-scale hydropower development, and few surveys of potential have been undertaken. However, provincial officials in Champassak province are considering the possibility of funding a micro-hydropower survey, which may indicate a rising awareness of the benefits of and potential for such schemes in the country. Also, the Department of Irrigation and Micro-hydropower have collected data for eight projects, two of which are in the preparation stage and one is under construction [Phalasack Pheddara, 1992 (b)]. They have a further 50 projects which they wish to study, which from map assessments have a total capacity of approximately 7MW [Phalasack Pheddara, 1992 (a)]. In Luang Prabang, the provincial office of the Irrigation and Micro-hydropower Section of the Ministry of Agriculture and Forestry has twenty projects which it considers warrants detailed feasibility studies.

The Bolevan plateau has vast potential for both medium- and small-scale hydropower developments, particularly in the district of Phaksong [pc: Narongsack Sayakounh]. Here the villages are comparatively close together, cash crops are grown and the provision of

roads is better than most other regions in the country. There is a high demand for pumping for irrigation purposes, and for productive end uses in agricultural produce processing, as the land is very fertile and the climate favourable for the growth of both tropical and temperate crops and fruits. There are plans to develop a mini-hydropower scheme on the Sekatam river in this region [Houmphone Boulignaphonh, 1992].

The eastern parts of Saravan and Savannakhet, towards the border with Vietnam, has great hydro resources, but productive end use will be limited due to the low population density and the predominance of subsistence farming. There are plans for a scheme at Houy Sakhouang in Savannakhet, which will provide electricity for 220 families from two 50kW units operating from a head of 8.7m [pc: PMWWC]. Also in the South, the UNDP are to fund possibly one or two micro-hydropower schemes under their Integrated Rural Development Project Sekong-Dakchung. They consider there to be two promising sites, of around 25kW, near to the village of Dakchung [pc: Kurululasuriya]. The main objectives of the project are to provide electricity to the community of about 200 families and to power a rice mill by direct drive. There are also plans for a second stage which would supply power to the local sawmill and mechanical workshop.

In the northeastern province of Houaphanh, there are plans for the development of a hydropower site with three turbines of 560kW each. The government is also joint funding the feasibility studies for a further three projects of 72kW, 110kW and 36kW, with heads of 11m, 28m and 6.8m respectively [pc: Preston], although the present estimated demand for these three sites is less than 10kW in each case. Also in the North there are plans for a 200kW scheme at Nam Gnome, Bokeo province, near to the Lao, China and Myanmar borders. It has also been suggested that resettlement sites for refugees, especially in the northern province of Sayaboury, could be ideal for micro-hydropower development [pc: Inversin (a)].

The two pilot micro-hydropower schemes built with funding from the Mennonite Central Committee were funded with the aim of promoting future developments throughout the country. They had plans to publicise the technology by distributing leaflets and via broadcasting on state radio and television [pc: Foehringer], but as yet their plans have not come to fruition.

5.4.6. Requirements for micro-hydropower development

In order for micro-hydropower developments in the country to be sustainable, a clearly defined policy should be established so that governmental organisations and NGOs can be

part of a national programme. This will allow funding agencies to continue their work in the country, within set guidelines, so that the recipients are not left with equipment which cannot be repaired by Lao engineers.

The creation of a mechanism to provide rural credit is required to support those who wish to invest in their own scheme, for those wishing to pay for distribution and house wiring to connect to an existing scheme, and to help finance repair of those schemes which are presently out of service.

There is a need for a technical back up service which is able to provide repair and overhaul services to those sites which are already in existence.

Greater thought needs to be given to the post-construction phase of the projects, including greater focus being placed upon productive end usage. There is a need to train the staff of those organisations involved with the implementation of schemes, in the financial aspects affecting a project's viability.

5.5. LOCAL MANUFACTURE OF HYDROPOWER EQUIPMENT

5.5.1. Introduction

The Lao PDR is at an early stage of developing its local manufacturing capabilities, with very few turbines having been fabricated in the country.

5.5.2. Government policies towards local manufacture of hydropower equipment

The government has no policy concerning local manufacture of equipment, and Lao government officials encourage the acquisition of equipment from any source. The majority of equipment for hydropower schemes has been imported from abroad, particularly from China, Vietnam, Germany and Nepal.

Until recently, all factories within the country have had to be under the auspices of one of the government ministries. Since the recent reforms, some private workshops have emerged, and thus equipment can now be made by the private sector. Russia had proposed a joint venture with a Lao manufacturer to produce small hydropower components, but this has not as yet come to fruition.

5.5.3. Acquisition of technological capabilities

Water powered devices have traditionally been made in the region for hundreds of years, probably being acquired from the Chinese to the north. More recently two independent organisations copied designs from a SKAT publication which provides detailed plans for a crossflow turbine. An employee of the Investigation and Design Centre for Hydropower Projects was sent on a on small-scale hydropower design course in Japan. On his return to the country he fabricated a 40kW crossflow turbine based upon a SKAT publication for a site at Nam Ham [pc: Viraphanh Nandavong]. Other technology has generally been acquired from foreign experts involved in the feasibility study, or construction of schemes. In one case, an expert from the United States of America was employed to develop the two Mennonite Central Committee schemes, during which time it is apparent that the colleagues with whom he worked gained a good appreciation of the tasks involved.

A law on Foreign Investment was approved in the Lao PDR in 1988, however, all laws related to business are under review by the Foreign Investment Management Committee [ECIU, 1993]. It stipulated the type of agreements which may be entered into by potential investors as being:

- contractual business cooperation - that is investment in an existing state, or private sector company;
- joint ventures;
- private ventures with up to 100% foreign capital permitted.

As is the situation in Vietnam, there is a minimum foreign investment in a joint venture agreement of 30% of the total capital of the enterprise. Both imports and exports require permits from from the Ministry of Commerce and Tourism [UN, 1991].

The Lao PDR offers few locational advantages to non-Thai foreign investors and suffers from poor transport and communications infrastructure, and a lack of skilled labour and managerial experience, all of which increase investment risk. With the legal structure relating to business still being developed, laws and regulations are likely to change, resulting in an uncertain environment which is not ideal for potential investors. As an incentive to foreign investors, tax incentives have been made available for priority products.

The Lao PDR is a member of ESCAP and a signatory to the Bangkok Agreement for liberalised trade among developing countries of ESCAP, which aims to liberalise trade and provide for preferential duties that encourage increased intra-regional trade. It is not, though, a member of GATT. Bi-lateral trading agreements have been made with Vietnam, with whom they have established a Committee for Economic and Cultural Cooperation.

Regulations on patents have only recently been drafted, and are the responsibility of the Ministry of Science and Technology. Industrial patents of technology are presently protected if the holder of the patent is licensed at the Board of Management of Foreign Investment.

5.5.4. Turbines

In the provinces several micro-hydropower schemes have been assembled using wooden waterwheels connected to old generators. Very few metal turbines have been fabricated, and the few constructed to date have all been of a crossflow design.

One organisation in Vientiane has produced three crossflow turbines based upon a SKAT design [pc: Lam Ngeunh Phakaysone (a)]. Only one of the units has been put into operation, as the other two are being used for display purposes. The turbines and casings were fabricated at local workshops, with assembly and development being undertaken by staff of a local organisation, Techno Phatthana Khetphoudoi.

EDL in Luang Prabang has used a locally manufactured turbine to supply approximately 70 households with electricity for lighting [Inversin, 1991 (a)]. The scheme has recently broken down due to failure of one of the bearings, and it is not likely to be repaired due to the high costs involved [pc: Ban Tha Paen].

Another scheme built at the Agricultural Tools Making Factory in Vientiane in 1986 failed after three years of operation due to wearing of the blade, and is now being replaced by equipment from Germany. The design for the 40kW crossflow runner was again based upon a SKAT design. The cost of the runner was approximately 280,000 Kip (US$2,947 - using the official commercial exchange rates in 1986; or US$700 - using the parallel exchange rate in 1986), and the total cost for the turbine and generator came to 800,000 Kip (US$8,421; US$2,000). These costs were met by the government, but as the scheme designer had promised at least 5 years of operation, no more money has been granted for local repair, or for further manufacture of equipment. It is thought that the

failure of the turbine was primarily due to inadequacies in the de-silting design at the site and not due to problems with the blade itself [pc: Viraphanh Nandavong]. The cost of US$50/kW installed for the turbine and generator at the parallel exchange rate is exceptionally low, as can be seen in comparison to the costs of equipment from other sources, as shown in figure 2.5. Now all government sponsored schemes require donation of the electro-mechanical equipment from abroad, as government funding is usually provided for only the civil works.

5.5.5. Generators

Throughout the country, many disused diesel generators are available at a very low cost. After reconditioning, some have been used as generators for micro-hydropower schemes. An old Czechoslovak diesel generator costing 100,000 Kip (US$1,052; or US$250) in 1986, was used for a 40kW scheme established by the Ministry of Handicrafts and Industry [pc: Viraphanh Nandavong]. This cost may be unrepresentatively low, as it was obtained from the Ministry's stock of equipment, and in the market place the cost may be much higher [pc: Lam Ngeunh Phakaysone (a)]. Still the cost of a renovated generator is low in comparison to that of a new generator from Thailand, China, or else where. No generators are manufactured within the country.

5.5.6. Governors

No governors have so far been made in the country. The majority of schemes installed by NGOs have mechanical governors imported from abroad, although some schemes rely upon manual governing. The lack of a cheap and reliable governor for small-scale sites is a problem which has led to the run down of at least one site. At Ban Phak Kout, Lao Ngam District, Saravan province, a 25kW scheme built by the Vietnamese in 1987 stopped working three years later due to inadequate maintenance and repair. The village now has a diesel generator, and as the micro-hydropower scheme requires manual operation, the villagers are not prepared to consider the project's renovation, unless some form of automatic governing is installed [pc: Viengsavana].

Techno Phatthana Khetphoudoi have expressed their interest in acquiring the technology necessary to assemble and construct ELCs, for use in the country.

5.5.7. Family-hydropower equipment

At present most Family-hydropower units bought within the country are imported from China, and no equipment has been made within the Lao PDR. The Agricultural Tools Making Factory in Vientiane is presently considering manufacturing Family-hydropower equipment, however, they are unsure of how to obtain the permanent magnets for the generator [pc: ATMF].

5.5.8. Other equipment

Penstocks have been manufactured at the Agricultural Tools Making Factory, and can be fabricated at several provincial workshops. Several privately owned and ministerial workshops in Vientiane, and some workshops in the provinces are capable of making repairs to turbine and generator equipment, and fabricating many types of mechanical components. All the necessary electrical equipment, including transformers, cables and protection equipment must presently be imported.

A pole making factory has been established to provide for rural electrification developments [Saetersmoen, 1992]. Prestressed spun concrete poles are used as they have a longer expected lifespan than wooden poles, however, wooden poles are used for smaller schemes below 200kW [Sumphorn Manodham, 1992].

5.5.9. Assessment of companies involved in manufacture of hydropower equipment

Agricultural Tools Making Factory, Vientiane

This factory, owned by the Ministry of Industry and Handicrafts, was established in 1972 and employs approximately 120 people. They are presently producing pumps and agricultural threshers, and the demand for their products often exceeds their production capacity.

The factory has an iron foundry, welding facilities, a cutting machine, heat treating facilities, lathes and drilling machines. They have fabricated many penstocks, and have a bending machine which is capable of forming penstocks with a wall thickness of up to 15mm. Some bronze casting has been undertaken at the factory, although this is comparatively expensive and cast iron is more typically used. Two of the four foundries situated in the country are to be found at this factory. The gray iron foundry, with a 200 tons/annum capacity is the only foundry in the country which is in sustained use [UN,

1990 (c)]. Coke for the foundry is imported from Thailand and Vietnam, and scrap steel is obtained locally. Molding is done manually, with the drag side of the mold embedded in the sand floor, and the cores are baked on open charcoal ovens. Figure 5.10 shows the mold produced for the casting of a pump casing at the factory. The 60 tons/annum steel foundry is in a state of disrepair after the electric arc furnace was hit by lightning [UN, 1990 (c)]. Visual inspection is the only form of inspection, as there are no instruments available at the foundry. Skilled manpower for the two foundries was attained with the help of two trained Vietnamese who work at the factory.

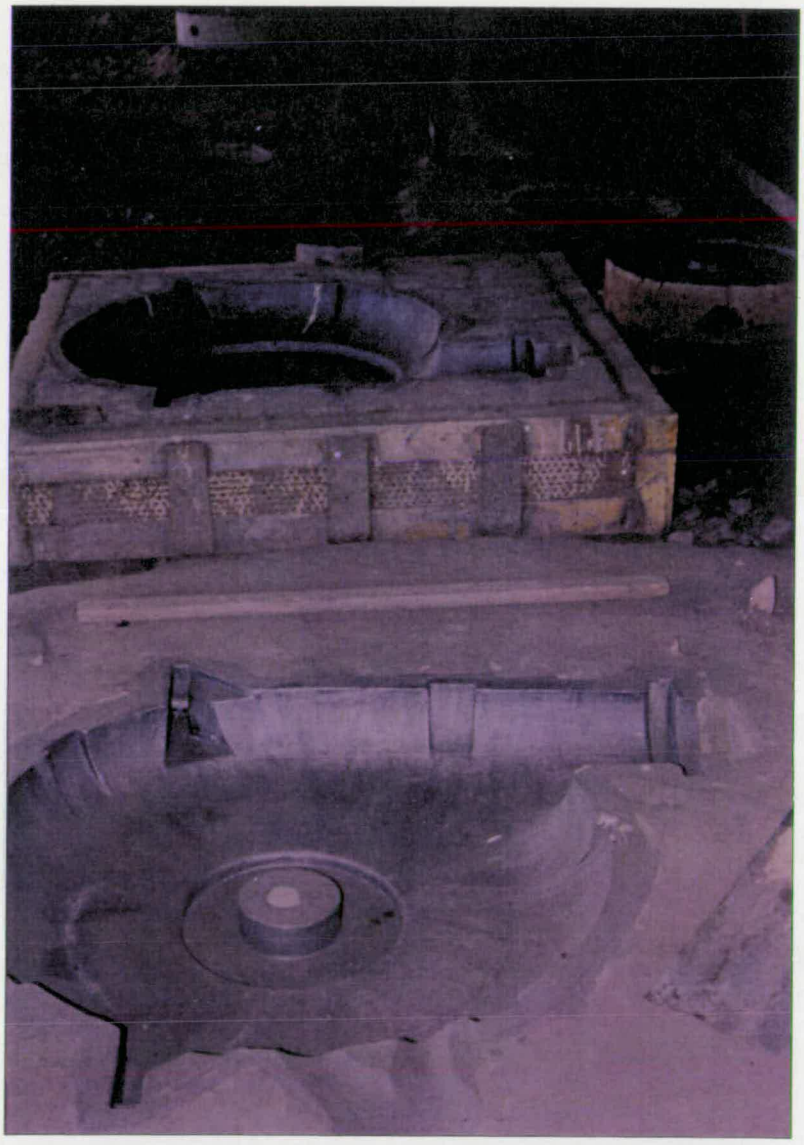


FIGURE 5.10: The casting mold for the casing of a pump at the Agricultural Tools Making Factory, Vientiane

A crossflow turbine designed by an employee of the Ministry of Industry and Handicrafts, and based upon a design published by the SKAT, was fabricated at the factory. It was designed for a head of 14 metres and a capacity of 40kW, and it took approximately one month to manufacture. The scheme used a generator renovated from a disused diesel generator. Also, turbines have been repaired at this factory in the past.

The organisation is currently investigating the prospects for manufacturing Family-hydropower units. Although the workshop appears to be capable of manufacturing crossflow turbines, it is not capable of designing, or installing the equipment, and for future schemes they would have to rely upon a coordinating organisation.

Techno Phatthana Khetphoudoi, Vientiane

Techno Phatthana Khetphoudoi is a privately owned organisation based in Vientiane, which has received funding from foreign charitable organisations. They have been involved in the production of three crossflow turbines, the designs for which were again based upon information obtained from a SKAT publication. The organisation assembled and coordinated the construction, and sub-contracted the manufacture of component parts to a small workshop in Vientiane. One of the turbines has been installed, whereas the other two have been used for display purposes.

One of the organisations engineers is involved, along with Chinese engineers, in the installation of a 1.6MW scheme, utilising Chinese equipment [pc: Lam Ngeunh Phakaysone (a)].

Irrigation and Micro-hydropower Equipment Factory, Vientiane

This factory was set up with aid from the United Nations Development Programme (UNDP), and is owned by the Department of Irrigation and Micro-hydropower of the Ministry of Agriculture and Forestry. The factory is currently not being used, however, in the past they have manufactured agricultural products including poorly designed ram pumps which tended to break after a short period of use. The workshop has several machine tools, including lathes and drilling machines, and the owners are wanting to put the factory to some use. Being part of the Department of Irrigation and Micro-hydropower, they would prefer that the factory be used to manufacture micro-hydropower equipment, amongst other things, but they presently do not have the financial resources,

skills, or man-power to do so.

Other local manufacturing and repair facilities

There are several small workshops in Vientiane which have the skills and machinery necessary to produce the components of a crossflow turbine. These private organisations have a reputation for producing accurate work with the right advice [pc: Lam Ngeunh Phakaysone (a)]. Most of these workshops have been set up over the last few years. Most work which they undertake is commissioned by other organisations or individuals and they are not capable of designing micro-hydropower equipment. There does not appear to be the incentive to produce equipment for the market place.

Several of the country's other major towns have workshops which are capable of repairing micro-hydropower equipment, given adequate information about the task required. Several very small hydropower schemes (5kW and less) have reportedly been built around the country, by local workshops, though they are generally not efficient and most have been empirically designed and built [pc: Inversin (c)]. A workshop on the outskirts of Pakse, in Champassak Province, which was also established with funding and expertise from the UNDP, has repaired equipment from a local micro-hydropower scheme. The workshop has a work force of over 30 people and is capable of repairing most of the mechanical components of a micro-hydropower scheme. A turbine runner has been repaired here and a new bearing fitted, when the original had failed after not being adequately greased.

The National Polytechnic of Vientiane has produced a 1kW scheme for a hospital in the province of Xiang Khouang. They also helped in the production of a 40kW scheme for a village in the same province [Viengxay Souvannakhot, 1992]. Also, the local office of EDL in Luang Prabang has built several water powered rice mills, but all are out of operation due to bearing failure [pc: Ban Tha Paen].

5.5.10. Test facilities

At present there are no hydropower test facilities in the country. The National Polytechnic in Vientiane are considering constructing a hydraulic machine testing laboratory in the near future [Viengxay Souvannakhot, 1992], though it is uncertain whether this will be for general use, or solely for the Polytechnic's own applications.

5.5.11. Assessment of the local manufacturing capabilities

Traditional wooden turbines have been made within the country for centuries, but the majority of modern equipment presently installed in the Lao PDR is imported. Only a few turbines have been manufactured locally, all of them crossflow designs based upon a published design. There is a general lack of adequate expertise, and there is an acknowledged need for training, both in manufacture and scheme design.

Whereas the Agricultural Tools Making Factory appears to be capable of manufacturing crossflow turbines, it is not capable of designing, or installing the equipment. The cost of manufacturing crossflow equipment has been very low, however, the efficiency and reliability of this equipment is also considered to be low. Fabrication of other types of hydropower turbines have not been attempted as yet. The manufacture of Francis turbines would be more difficult, and a process of technology transfer would need to be undertaken in order to manufacture this equipment within the country. Engineers at Techno Phatthana Khetphoudoi are capable of coordinating the fabrication and installation of small micro-hydropower schemes, and by using local workshops, they have produced several turbines.

5.5.12. Requirements for local manufacture

It is evident that the donation of foreign equipment undermines the local manufacture of equipment in the Lao PDR, and does little to encourage a nation-wide programme. Standards for micro-hydropower equipment have been set by this foreign equipment, thus inhibiting the contribution of funds to local manufacture which will initially be unavoidably of a lower efficiency and reliability than the foreign equipment. Thus without proven manufacturing capabilities, NGOs seeking to install a scheme have no option other than to buy foreign equipment. The authorities should acknowledge these facts, so that local manufacture may be protected and further funded, which will thus also enhance the repair facilities available within the country. Without a coordinated approach, many different types of foreign equipment are being imported into the country, leading to increased difficulty in the supply of spare parts, training and maintenance. There is a need for further training in turbine manufacture, as it is not wise to promote local manufacture whilst the country is lacking adequate expertise and experience.

To build up the manufacturing capabilities within the Lao PDR it is advisable to concentrate initially upon producing crossflow turbines of capacities below 50kW, and to aid in the transfer of technology and know-how in order to manufacture Family-

hydropower units. Equipment should be imported initially, whilst local manufacturing capabilities are further established. Designs for other types of turbines, and for all schemes with capacities above 50kW, will require further technology transfer.

It is thought that the majority of villages will have a maximum demand of only 20kW, and therefore a standard range of equipment could be designed, for a variety of heads, in order to reduce initial costs. Many micro-hydropower schemes rely upon manual governing, which is not always feasible to achieve, nor appreciated by recipient villagers. ELC technology could be appropriately used in many cases, having either been imported, or produced locally if the technology were to be adequately transferred.

5.6. CHAPTER SUMMARY

Less than 2% of the rural population of the Lao PDR have access to electricity. The terrain of the country, the high levels of rainfall and the dispersed population make small-scale hydropower developments a suitable choice for rural electrification. With a relatively poor and small population, the size of the market for such equipment is likely to be initially low, restricting economies of scale. Also in most areas, villages are too dispersed for mini-hydropower developments to be economical other than for some provincial towns. The country suffers from poor infrastructure and financial resources are extremely limited, with the country being reliant upon aid from other countries for much of its technological equipment.

So far, more than twenty micro-hydropower sites have been built, nearly all with outside assistance. Their development has been erratic and piece-meal, mainly due to the number of agencies and suppliers of equipment involved. Many of the schemes are in a state of disrepair, or are operating at low efficiency, and local engineers are not able to obtain the necessary spare parts, and are often inadequately trained to perform the repair tasks required.

Only a few crossflow turbines have been fabricated within the country. To build up the manufacturing capabilities within the Lao PDR it is advisable to concentrate initially upon producing crossflow turbines of capacities below 50kW, and to seek aid in the transfer of technology and know-how to manufacture ELCs. Present capabilities are adequate for the production of Family-hydropower units if there is the will to do so. It is considered that designs for equipment other than crossflow, and for all schemes with capacities above 50kW, will require outside assistance. Equipment must continue to be imported, but more emphasis should be placed upon the provision of spare parts, and at

the same time providing training in the manufacture of micro-hydropower equipment to local technicians and engineers. It is suggested that if organisations are sincere in their wish to promote the sustained use of micro-hydropower within the country, then they should help fund the establishment of local manufacturing capabilities, rather than funding one-off schemes which ultimately undermines the fledgling local manufacturing industry.

CHAPTER SIX:
COUNTRY STUDY - THAILAND

6.1. COUNTRY PROFILE

Thailand lies in the tropical monsoon zone of southeastern mainland Asia, where the annual average rainfall is between 1,000 to 3,000 mm/year [Lucas, 1987]. With a population of 56.3 million (1990) and a land area of 513,115 square kilometres [Chulapongs Chullakesa, 1992], it has one of the lowest population densities of the middle income countries in Asia and the Pacific. Urbanisation is comparatively low at approximately 15%, with the majority of these living in the capital, Bangkok [Lucas, 1987].

The country comprises of four distinct geographical regions. The northern region is mountainous and heavily forested, extending into the southern reaches of the Himalayas. The Central Plain, through which the Chao Phraya river flows, is the most fertile and productive agricultural region. The country's northeastern plateau is relatively infertile, and it is the most heavily populated. The long peninsular of the South is characterised by hills, coastal swamps and mangrove forests, where much rubber, palm and fruits are grown [Lucas, 1987].

Thailand's economy is expected to grow at between 7 to 8% per year during the next few years [TDRIF, 1991], making it one of the fastest growing economies in the world. Although the country has seen rapid industrial growth over the last 25 years, agriculture is still the basis of the economy. 62% of the working population are employed in agriculture, which contributed to 17% of the country's GDP, whereas manufacturing accounted for 24% (1988). Electronic integrated circuits were the country's seventh top export earner (1988) worth 18,855 million Baht (US$754 million) [UN, 1990 (a)]. Thailand's principle trading partners are Japan, the United States of America, and the other countries of the ASEAN.

Monthly rural household incomes vary widely from region to region. The Northeast has the lowest average income levels, whereas those in the North are only slightly greater, with average incomes being 13% and 23% respectively of those in Bangkok [Lucas, 1987]. The hills to the North are the home to numerous hill-tribe communities who are amongst the most economically disadvantaged people in the country.

6.2. ENERGY SITUATION

6.2.1. Energy supply and demand

The country's fast rate of economic expansion has led to a rapidly rising demand for energy, particularly in the transport sector. In the three years between 1987 to 1990, commercial energy consumption rose from 388,000 barrels of oil equivalent per day (boe/day) to 605,000 boe/day (see figure 6.2), an average rise of 16% per year [NESDB, 1992 (a)]. Thailand has proven reserves of natural gas, lignite and oil (40%, 57% and 3% respectively in terms of boe) equivalent to 50 to 60 years consumption at the present rate of use, and there are also indigenous hydropower and geothermal resources. Domestic energy production has risen to 250,000 boe/day, representing approximately 38% of the country's primary commercial energy demand in 1990 [NESDB, 1992 (a)], giving rise to a high proportion of commercial energy needing to be imported. Over 98% of imports are petroleum products, the remainder being coal, and electricity purchased from the Lao PDR and Malaysia [TDRIF, 1991]. With primary energy consumption being expected to increase at a rate of 7.7% per year during the period of the Seventh National Plan between 1992 and 1996 [TDRIF, 1991], the government hopes to develop more domestic energy resources, and increase cooperation with its neighbouring countries in developing joint primary resources. Targets have been set to increase the commercial energy production to 410,000 boe/day by 1996, whilst maintaining the import dependency at approximately 60% [NESDB, 1992 (a)].

Traditional fuels are widely used and in the rural households, where traditional fuels supplied 79% of the energy consumed, charcoal is the most used fuel source, as can be seen from figure 6.3 [REDP, 1989]. Other traditional fuels used include rice husk, sawmill waste, and bagasse, a by-product of the sugar industry. Many rural consumers use kerosene lanterns to get a poor quality form of lighting, spending between US$2.50 - US$4.20 per month [Meridian Corporation]. Electricity use is increasing in rural areas as the supply network is extended and the rural population become more able to afford the tariff. However, charcoal and fuelwood remain the most economical fuels for cooking in rural areas. The structure and pricing level of energy does not fully reflect the true economic costs, and for political reasons they are not determined by the market [TDRIF, 1991]. The price of modern fuel does not vary widely with location even where distribution costs are high.

Use of fuelwood and charcoal is expected to decline due to increasing scarcity of resources, with each region being affected differently. In the North, there is ample



[Source: Nelles Verlag]

FIGURE 6.1: Relief map of Thailand

Source	Energy supply (boe/day)
Domestic production	**231,000**
Crude oil	24,000
Natural gas	109,000
Lignite	70,000
Hydroelectricity	25,000
Condensate	3,000
Imports	**374,000**
Crude oil	204,000
Oil products	165,000
Coal	4,000
Electricity	1,000
Total supply	**605,000**

[Source: TDRIF, 1991].

FIGURE 6.2: Primary commercial energy supply in Thailand (1990)

Energy balance by end-use			Energy balance by fuel type		
End-use	**(boe/day)**	**(%)**	**Fuel type**	**(boe/day)**	**(%)**
			Traditional fuels	**30,860**	**79**
Cooking	32,200	83	Charcoal	25,520	65
Lighting	4,650	12	Fuelwood	5,340	14
Refrigerating	760	2	Modern energy	**8,120**	**21**
Air-conditioning	20	-	LPG	1,330	3
Others	1,350	3	Kerosene	2,290	6
			Electricity	4,500	12
Total	**38,980**	**100**	**Total**	**38,980**	**100**

[Source: REDP, 1989].

FIGURE 6.3: Rural household energy balance in Thailand (1986)

although declining forest cover of approximately 50%. Demand for fuelwood is not considered to be a major threat, although other pressures such as logging, and land being cleared for agriculture are increasingly affecting this situation. Only 23% of the southern

region is forested, and with relatively high average income levels, commercial fuels are widely used. Use of biomass is balanced by the growth of fuelwood, however, export of charcoal from the area exceeds sustainable supply. The Central Plain has tree cover of approximately 30%, and here also, relatively high household incomes have led to substantial use of commercial energy, however, demand for fuelwood still exceeds production. Forty percent of Thailand's population live in the Northeast region of the country. Here, 98% of households use traditional fuels, and demand for fuelwood is over twice that of sustainable supplies. Forest cover in the region is anticipated to disappear by the year 2000 [Lucas, 1987]. A logging ban policy has been introduced in some areas [Green, 1991], and improved efficiency wood stoves are being promoted.

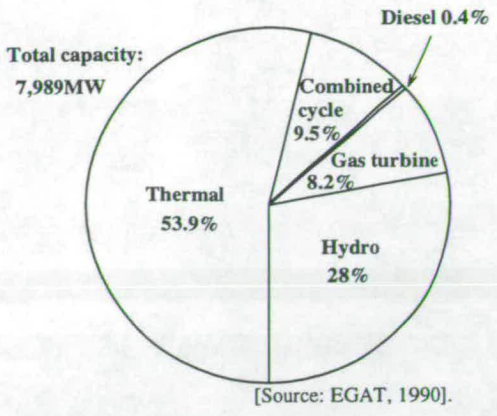
Six energy centres have been established throughout the country to promote new energy technologies and energy efficiency. The introduction of modern energy technologies to those areas without an electricity grid connection is slow, due to the low incomes of the people and the inaccessibility of the regions. Approximately 3,000 family-sized biogas units were built with government subsidies, but after problems with both their operation and maintenance, and the fact that charcoal was a cheaper option, the programme is considered to have failed [Lucas, 1987].

6.2.2. Electricity supply and demand

Over 99% of electricity generated and sold through the national grid network is produced by Electricity Generating Authority of Thailand (EGAT) [NEA, 1990]. As can be seen from figure 6.4, thermal and hydro generation account for the majority of the 7,989MW of installed capacity. The Provincial Electricity Authority (PEA) and the Department of Energy Affairs (DEA)‡ also generate some electricity for sale to the public, and some private organisations generate for their own consumption. The DEA hydropower schemes produced approximately 22 GWh of electricity in 1990, and the PEA generated 64 GWh during the same year [NEA, 1990]: combined, these represent approximately 0.2% of the total generated nationally. Some of the country's electricity is purchased from Electricite du Laos and the National Electricity Board of Malaysia [EGAT, 1990]. In recent years there has been a shift to gas and lignite to reduce dependence on imported fuels. Figure 6.5 shows the generation mix in 1990.

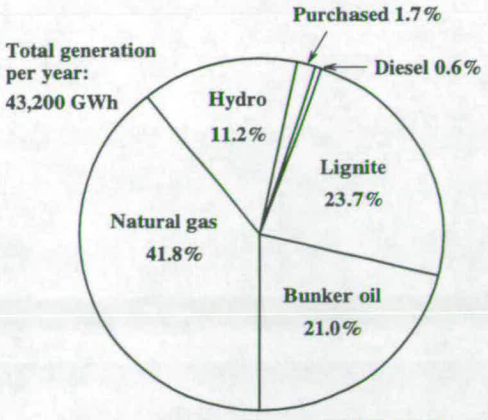
---

‡ The Department of Energy Affairs has taken over most of the responsibilities of the disbanded National Energy Authority (NEA).



[Source: EGAT, 1990].

FIGURE 6.4: Installed electrical capacity (1990) of Thailand



[Source: EGAT, 1990].

FIGURE 6.5: Electricity generation by fuel source (1990)

Electricity generation increased by an average of approximately 16% per year during the period of the Sixth National Plan (1987 to 1991), during which time it was estimated that the government investment was to be in the region of US$3.8 billion [Hagler, Bailly and Company, 1986]. Due to the rapidly rising demand for electricity, during the Seventh National Plan (1992 to 1996) a massive increase in the country's installed generating capacity of 5,400MW is proposed [NESDB, 1992 (a)], and by 2006, it is planned that there will be a further 14,500MW. Of these developments, 14,350MW is expected to be thermal plant, 1,752MW from new hydropower installations, and the remainder from combined cycle and gas turbine stations [EGAT, 1990]. Use of lignite for electricity generation is expected to rise four-fold by the year 2002 [NESDB, 1992 (a)], even though pollution problems experienced at the 1,425MW Mae Moh thermal power station recently led to the partial closure of the plant. Most of the economically feasible large hydropower resources within the country have been developed, however, there are still large joint resources available on its borders with the Lao PDR. Negotiations into the development of these resources is to be speeded up during the Seventh National Plan [NESDB, 1992 (a)], and it is said that 10-15% of Thailand's electricity is to be generated in the Lao PDR in the future [Dansie, 1994]. Recent large hydropower developments have been met by considerable opposition, requiring EGAT to become aware of the need to consider the environmental and social consequences of its developments.

Government investment into large-scale power projects is restricted due to the country's large foreign debt. In order to overcome the shortage in capital the government is attempting to encourage private-sector participation by encouraging Build-Own-Operate ventures for large plant [NESDB, 1992 (a)]. Until recently only government organisations have been able to generate and supply power, with no provisions being made for purchase of electricity from independent generators. By 1996, cogeneration schemes funded by private investment are expected to contribute 500MW to the installed

capacity [NESDB, 1992 (a)], however, as yet no firm purchase agreements have been made. If energy prices were at their true costs then the economic feasibility of new schemes would improve.

Electricity generated by new thermal plant costs EGAT in the region of US$0.045/kWh. EGAT is looking at ways of purchasing more electricity from the Lao PDR as production costs are expected to be approximately US$0.02/kWh for the Nam Theun II project [Government of Lao PDR, 1989]. The cost to the PEA of electricity generated by EGAT is 1.04 Baht/kWh (US$0.042/kWh). The cost of production of electricity from the PEA's mini-hydropower stations is estimated to be between 0.65 and 0.99 Baht/kWh (US$0.026 to US$0.040/kWh), and as much as 5.00 Baht/kWh (US$0.20/kWh) for diesel generation [Chulapongs Chullakesa, 1992].

Tariff rates vary according to different power usage and the type of consumer, including residential, small business, large business, small industry, large industry and water pumping. As can be seen in figure 6.6, the residential tariff rate ranges from 5 Baht/kWh (US$0.20/kWh) for the first 5kWh, down to 0.70 Baht/kWh (US$0.028/kWh) for the next 5kWh used per month, with a minimum charge of 5 Baht (US$0.20) being made [NEA, 1990].

The PEA are in the initial investigation stages of their possible future use of renewable energy sources for remote villages and island communities. A reduced import tax of 5% (from 35%) on renewable and cogeneration plant has been granted in order to promote the use of this equipment [pc: Prida Wibulswas]. The organisation presently has seven mini- and micro-hydropower plants, three solar plants and one wind power plant with a peak capacity of 80kW, [Reungvith Vechasart, 1990]. Three villages have been provided with solar energy equipment of 50kW, 50kW and 20kW capacity, with the aid of Japanese finance [Reungvith Vechasart, 1990]. Four 20kW wind powered generators are planned for the island of Pha Ngan, and consideration is being made into connecting other islands via submarine cable [Hagler, Bailly and Company, 1986].

EGAT have also established several renewable energy systems, both for its own use and in response to special Royal requests to benefit specific hill-tribe villages. A hybrid 5kW photovoltaic and 18kW wind generator system has been connected to the local island grid on Pucket, and elsewhere a demonstration hybrid 20kW photovoltaic and 20kW hydro grid connected system has been established. Other non-conventional EGAT plant include a grid connected 300kW geothermal scheme, a 50kW phosphoric acid fuel cell demonstration plant and three horizontal axis wind generators of 0.7kW, 1kW and 2kW

	Tariffs	
Residential tariffs		
First 5kWh or less	5.00 Baht	US$0.204
Next 10kWh	0.70 Baht/kWh	US$0.041/kWh
Next 10kWh	0.90 Baht/kWh	US$0.037/kWh
Next 10kWh	1.17 Baht/kWh	US$0.048/kWh
Next 65kWh	1.58 Baht/kWh	US$0.065/kWh
Next 50kWh	1.68 Baht/kWh	US$0.069/kWh
Next 150kWh	1.76 Baht/kWh	US$0.072/kWh
Next 100kWh	2.02 Baht/kWh	US$0.082/kWh
Next 400kWh	2.11 Baht/kWh	US$0.086/kWh
Next 800kWh	2.43 Baht/kWh	US$ 0.099/kWh
Agricultural pumping tariffs		
First 100kWh or less	117.00 Baht	US$ 4.776
Over 100kWh	1.17 Baht/kWh	US$ 0.048/kWh

[Source: NEA, 1990]

FIGURE 6.6: Electricity tariffs for residential and pumping usage in Thailand

which have been set up for experimental purposes [Jivacate Chaya]. Photovoltaics have also been used by EGAT and other organisations for communication repeater stations and other low power uses. There are three manufacturers of photovoltaic modules in Thailand, each operated with foreign backing under joint venture contracts, with the majority of the equipment being exported [Jivacate Chaya].

6.3. RURAL ELECTRIFICATION

6.3.1. History of rural electrification

Electricity was first used in Thailand for lighting at the Royal Grand Palace, Bangkok in 1884. The first public supply was commissioned in 1897, and during the first half of this century a number of foreign organisations, both within and outside of Bangkok, generated electricity for their own use and often sold electricity to nearby residents. It was in the 1930's that public distribution to the provinces began [Chulapongs Chullakesa,

1992]. In the 1950's, with the building of the country's first hydropower dams, rural areas around the sites received electricity [Helling, 1986]. During the 1960's many villages were electrified by the use of diesel generators [Ramani, 1988], and by 1970, 2,446 villages had been electrified. At this time the expansion rate was approximately 245 villages per year [Chulapongs Chullakesa, 1992], but with 45,000 villages still without electricity, it would have taken more than a hundred years to provide electricity to them all. In 1973, 'The National Plan for Thailand Accelerated Rural Electrification' was approved by the Royal Thai Government. This plan detailed the strategy for achieving 98% to 100% rural electrification coverage over the following 25 years [Chulapongs Chullakesa, 1992].

6.3.2. Government policy towards rural electrification

The Royal Thai Government has been eager to promote the electrification of rural areas. Initially the priority of the government was to provide electricity to areas which were considered to be economically underdeveloped, or politically unstable [Chulapongs Chullakesa, 1992]. Both government and international funds have been used for the programme. In general the interest rate on loans obtained for rural electrification development have been low, at a two percent, repayable over 30 years, after a 10 year grace period [Manandhar, 1982]. The government's objectives, as approved by the National Economic and Social Development Board (NESDB) are shown below in figure 6.7.

	Period	Electrified villages (%)
3rd National Plan	1972 - 1976	30
4th National Plan	1977 - 1981	50
5th National Plan	1982 - 1986	76
6th National Plan	1987 - 1991	94
7th National Plan	1992 - 1996	98 - 100

[Source: Chulapongs Chullakesa, 1992]

FIGURE 6.7: Rural Electrification target for each Thai National Plan

6.3.3. Rural electrification agencies

The Provincial Electricity Authority (PEA), is the principle agency concerned with rural electrification within Thailand. It has the responsibility for the electricity distribution

services throughout the country, except within the Metropolitan Area of Bangkok which is under the responsibility of the Metropolitan Electricity Authority (MEA). The PEA obtains the majority of its electricity from EGAT, which is responsible for the generation and transmission of electricity throughout the country.

The Department of Energy Affairs (DEA) is also partly concerned with rural electrification via its remit to disseminate, demonstrate and promote the use of suitable new and renewable energy technologies to rural villages. Their work has principally focussed upon rural energy supplies for isolated communities. These have mainly been mini-hydropower and micro-hydropower schemes, which will be described in greater detail in section 6.4. Difficulties have arisen in some instances whereby, due to failures in updating the status concerning electrification of villages, some projects have been planned where electricity has already been provided either by a different department within the PEA, or in some instances the NEA [Manandhar, 1982].

6.3.4. Extent of rural electrification

The PEA has three schemes by which to extend electrification to those villages which are unelectrified. These are [Chulapongs Chullakesa, 1992]:

- the Accelerated Rural Electrification Program - the government funded programme whereby villages are provided with an electricity supply in accordance with the PEA development plan;

- the Contribution Scheme - this scheme allows villages which are not likely to receive a supply in the near future to reduce their waiting time, under the condition that they contribute 30% of the expansion cost while the PEA funds the other 70%;

- the Individual Consumer - for those villages which are willing and able to pay 100% of the expansion costs, so as to avoid having to wait for the time-scheduled project. Less than 1% of villages take this option.

Also, the Volunteer Self Development and Defence Village Electrification Project provided electricity to approximately 100 villages per year, with village selection criteria being defined by the country's Internal Security Operation Command [Manandhar, 1982].

The majority of villages are connected by the PEA's 150,000km (1990) of 22kV and 33kV distribution line [NEA, 1990]. There are also some diesel sets which provide

electricity to some of those villages beyond the range of the grid. Although coverage of tambons† is nearly complete, there are many unserved villages within electrified tambons. Also many households within electrified villages do not have a connection, because they are unable to afford the cost of a connection [Helling, 1986]. In 1990, although approximately 91% of rural districts had been electrified, only 71.5% of the rural population had access to electricity. The percentage of people with an electricity supply was highest in the Central region and as low as 65% in the southern region [NEA, 1990]. Figure 6.8 shows the present extent of electrification throughout the country at the different local administrative levels.

Administration level	Total number	Number electrified	Percentage electrified
Province	70	70	100
District	794	794	100
Tambon	6,608	6,516	99
Village	61,205	58,044	94

[Source: Chulapongs Chullakesa, 1992]

FIGURE 6.8: Level of electrification at each level of local administration (1991)

By the end of 1991 approximately 94% of the 61,205 villages in Thailand had been electrified, and the PEA have plans to achieve 98% rural electrification by 1996 [Chulapongs Chullakesa, 1992], by which time the number of villages in Thailand is expected to increase to around 66,539. Figure 6.9 shows the growth in village electrification and the PEA's future plans for development. Approximately 1,200 villages, having in the region of 100 households per village [Meridian Corporation], will remain without electricity at the completion of the current plans. With the majority of these situated in the highlands, some in National Parks and others on islands [Chulapongs Chullakesa, 1992], grid extension is becoming less economically feasible due to the increasing marginal costs of reaching the smaller and more remote villages. The cost of transmission and distribution per village was estimated by the World Bank to be between US$26,000 and US$30,000 in 1983, and will now be considerably greater for those remaining villages.

† A tambon is a small administrative district consisting of a group of closely lying villages.

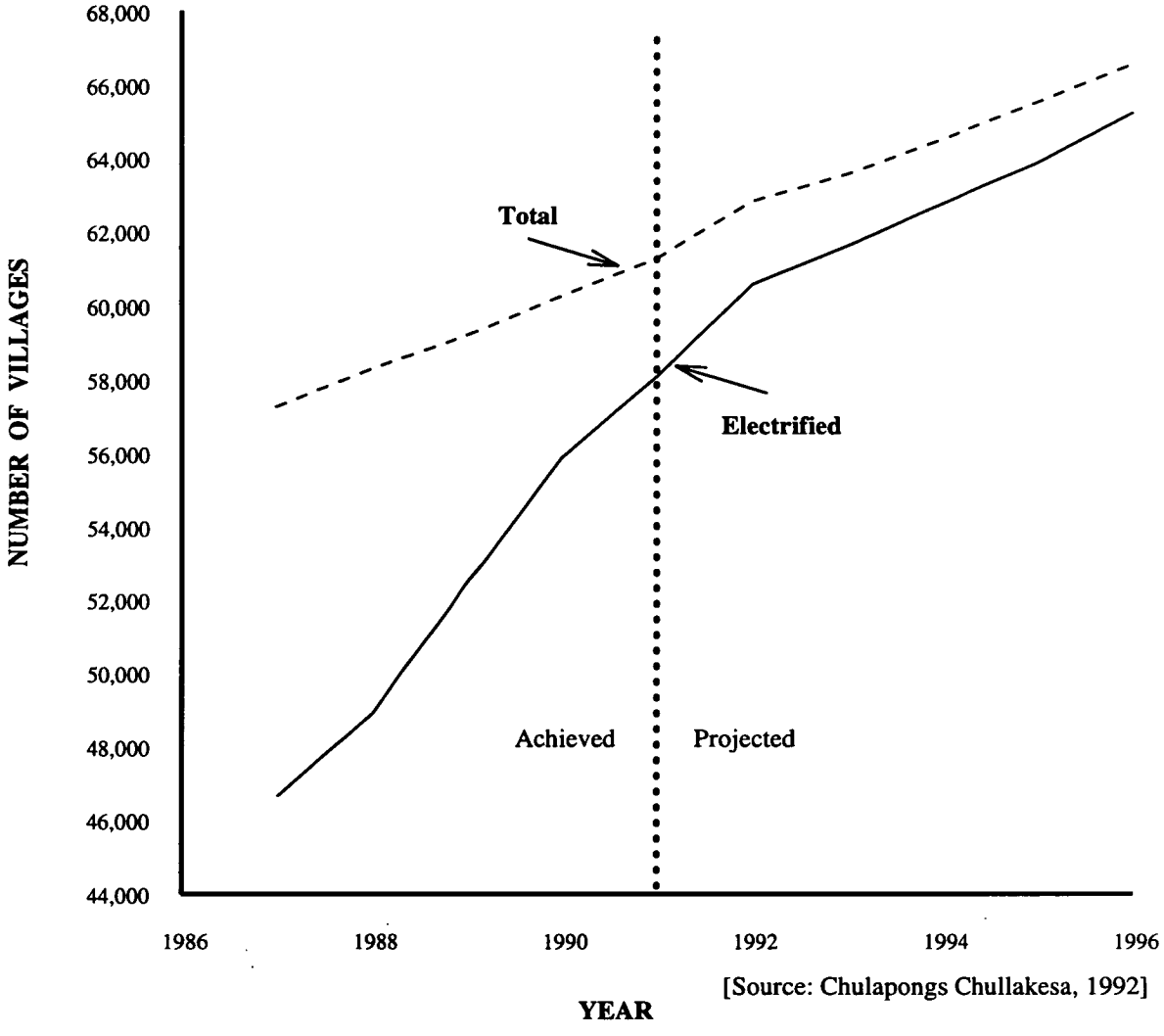


FIGURE 6.9: History and future of village electrification in Thailand

For the remaining 2% of villages which will remain outside the scope of the Accelerated Rural Electrification programme, the PEA is to investigate alternative approaches to electricity supply. Mini-hydropower and micro-hydropower, solar photovoltaic systems, wind turbines and biomass systems will be considered [Chulapongs Chullakesa, 1992], and advice will be given concerning effective and efficient usage of batteries for those villages with nearby charging facilities [pc: Chulapongs Chullakesa]. The effectiveness of this approach by the PEA will be affected by the fact that they have principally been involved with large scale distribution to many people, and have not had much experience with small one-off projects. The average cost of connection per rural customer is approximately 5,140 Baht (US$205) or 514,000 Baht (US$20,500) per village [Chulapongs Chullakesa, 1991 (a)].

Electricity consumption in Bangkok accounted for 47.7% of the total consumption for the whole country in 1990. Figure 6.10 shows the electricity consumption rates in the

country's regions. Tariffs for rural areas are equal to those in Bangkok, thus representing a subsidy to the rural users of about 47%, as the average operating costs for rural areas are 1.7 Baht/kWh (US$0.068/kWh) whereas average revenue is 0.9 Baht/kWh (US$0.036/kWh) [Green, 1991].

Region	Consumption/ capita/year (kWh)
Whole country	681
Outside MEA area	407
- Northern region	246
- North-eastern region	135
- Central region	1,071
- Southern region	361

[Source: NEA 1990]

FIGURE 6.10: Electricity consumption rates per capita throughout Thailand

Televisions and electric rice cookers are used by a large proportion of the rural population. At present approximately 55% of the PEA's household customers consume less than 35kWh per month [Green, 1991]. In order for rural electrification to be cost effective, the Load Promotion Programme is an important aspect of the PEA's rural extension work. One of the major loads in rural areas has been the use of rice mills, with approximately 30% of the 55,000 small rice mills in the country being electrically driven. With a typical energy consumption per month of 800kWh, a rice mill provides revenue of 1,200 to 2,000 Baht (US$48 to US$80) per month per machine [Chulapongs Chullakesa, 1991 (a)]. The PEA has initiated a nation-wide Power Load Promotion Programme to accelerate the conversion of rice mills from being diesel-driven to electrically driven [Chulapongs Chullakesa, 1992].

In areas without electricity, car batteries are popular for powering televisions, radios and for lighting. The initial cost of the battery is approximately 1,200 Baht (US$48) for a 65Ah, 12V battery, and a typical monthly expenditure is between US$2.90 to US$3.60 per household (US$1.50 to US$1.90/kWh) not including transport [Meridian Corporation]. This indicates villagers in non-electrified areas are willing to pay high prices for small amounts of electricity.

6.4. HYDROPOWER IN THAILAND

6.4.1. Introduction

Thailand's technically exploitable hydropower potential is approximately 7,000MW, plus a further 6,000MW from pumped storage. Hydropower accounts for 28% of Thailand's installed electricity generating capacity, with eleven medium and large hydropower schemes in operation, having a total capacity of 2,219MW. The technically feasible potential for small-scale projects of less than 6MW capacity is estimated to be 406MW [EGAT, 1989]. So far over 15 mini-hydropower and 50 micro-hydropower schemes have been developed.

6.4.2. Hydropower institutions

Future hydropower developments are to be coordinated by a joint committee including representatives from the DEA, PEA, EGAT and the National Energy Policy Office (NEPO). This will prevent duplication of effort which has been a problem in the past. A restructuring of the now disbanded National Energy Administration (NEA) has resulted in all energy policy making decisions being transferred to the NEPO, and changing the name of the NEA to the Department of Energy Affairs (DEA). The DEA now have the responsibility for research and development into energy technology, with its focus principally upon rural energy supplies for isolated communities. It is anticipated that the DEA will remain the principle organisation responsible for micro-hydropower development; the PEA will concentrate its efforts towards mini-hydropower schemes; and EGAT will remain with the responsibility for larger schemes [pc: Prida Wibulswas].

6.4.3. Micro-hydropower

NEA/DEA

Micro-hydropower schemes have been developed by the NEA/DEA in the North of Thailand since 1978. This followed a visit by the Secretary General of the NEA/DEA to small-scale hydropower systems in China, and the subsequent purchase of equipment for use in Thailand. Before this time, expatriates in southern Thailand had installed units for their own use, but the technology had not been made generally available [Helling, 1986]. The NEA/DEA is nearing the completion of a 75 scheme government sponsored micro-hydropower programme, for which it has been developing an average of six schemes per year [Helling, 1986]. Several other organisations, both governmental and non-

governmental, have also initiated one-off schemes.

The majority of the micro-hydropower schemes are situated in the North of the country in the provinces of Chiang Mai, Chiang Rai and Mae Hong Son. The NEA/DEA have a field office based in Chiang Mai from where they provide technical and supervisory services, and training in the operation and maintenance of the schemes. This infra-structure has been very effective in providing technical support for maintenance of the sites. Equipment and scheme designs are produced at the NEA/DEA's headquarters in Bangkok. It is generally considered that the NEA/DEA's programme has been successful [Chulapongs Chullakesa, 1992]. There are several peculiarities in the design of the schemes, such as the use of flywheels with ELCs, which indicate either a lack of understanding or a move to standardisation of designs [Brown].

Village participation in the civil works construction of schemes has been a prominent feature in the success of the NEA/DEA's programme. The first community initiated village electrification project was established in 1981, whereby villagers provided labour solely for the construction of the wier. This participatory approach is now used for all NEA/DEA schemes, with the technical support being provided by three NEA/DEA engineers and typically twelve additional staff [Helling, 1986]. The workforce is organised by a village committee responsible for scheduling labour during construction, which has been as high as 10,000 person-days of labour from one particular village [UNCTAD, 1989]. The committee is then also responsible for the operation and maintenance of the project once it is completed. In exchange, the villagers gain share equities in the scheme and have the opportunity to acquire full ownership of the project by purchasing the DEA's share (typically between 60% and 70% initially) with the revenue from the project [Hagler, Bailly and Company, 1986]. The tariff for electricity is at the same rate as that of the PEA supply, with the collected revenue after deduction of operation and maintenance expenses being divided amongst the shareholders [UN, 1988]. Unfortunately, nearly 15% of households participating in the construction of MHP systems are unable to consume as they cannot afford the costs of connection and wiring [Helling, 1986].

One of the drawbacks of the DEA programme has been the over-expenditure of the projects [Hagler, Bailly and Company, 1986], in part due to over-designed civil work constructions [Brown]. Village participation in the construction and use of local materials has reduced the cost of the schemes such that the cost of the civil works has been, on average, approximately 38% of the total project costs [Helling, 1986], down from 74% in the case shown in figure 2.2.

The DEA programme was undertaken with partial funding from the US overseas aid organisation, USAID. With this foreign aid they were thus able to investigate many different types of micro-hydropower technology and equipment. Initially this enabled the DEA to assess the equipment and structures which would be most appropriate to Thailand's needs, but this also led to an overspending. This has resulted in micro-hydropower being considered to be too expensive, and the economic viability of these schemes has not been demonstrated. This has affected the decisions of the policy makers who assess the options for providing electricity supplies to remote villages, and it has also resulted in the technology not appearing attractive to rural people wanting to develop their own scheme.

PEA

The PEA consider micro-hydropower projects to be 'pre-electrification' projects and not able to provide a reliable source of electricity [pc: Chulapongs Chullakesa]. Thus in some cases micro-hydropower schemes have been built in areas which have subsequently received a grid connection from the PEA. In such situations the hydropower scheme has been kept in operation in conjunction with the grid supply, although with separate wiring systems, but it is anticipated that when the schemes require any costly repair they will be left in a state of disrepair. As coordination between the different agencies is likely to improve under the new coordinating structure for hydropower developments, and as the PEA grid expansion scheme is coming to a close, this situation is becoming less likely to occur. Unfortunately this coordination does not include NGOs which are themselves involved in the establishment of micro-hydropower schemes.

With the expansion of the PEA grid there is perceived to be a decreasing need for micro-hydropower schemes. However, micro-hydropower does have an important role in those villages which lie outside of the areas to which the grid will be extended. With installation costs of between 24,000 and 73,000 Baht/kW (US$960 to US$2,920/kW), micro-hydropower is considerably more expensive than using a diesel supply in the short term, but is often the most cost-effective long term option for providing electricity to isolated villages far from the grid network.

NGO involvement

The Appropriate Technology Association (ATA), a NGO based in Bangkok, has built two village micro-hydropower schemes in the Mae Rim District of Chiang Mai, one of which is shown in figure 6.11. The organisation undertook its own technical and social

feasibility study as well as designing the schemes. The civil works and powerhouse were built with the participation of village members, who were also responsible for providing building materials such as sand, rocks and wood.

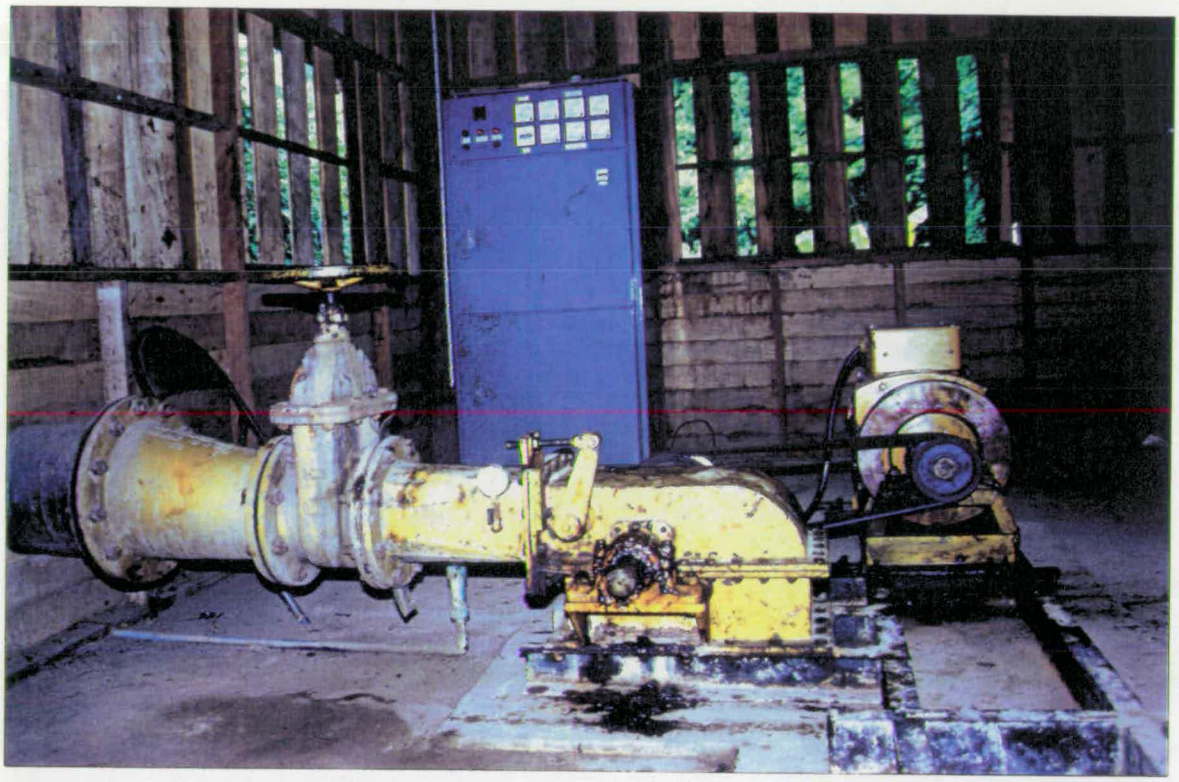


FIGURE 6.11: A 12kW crossflow turbine manufactured by the ATA, Bangkok, and installed at Muangka village, Chiang Mai province

Electricity from the schemes is used for domestic purposes and also for community uses, such as crop drying and rice milling. The schemes were commissioned in 1986 and 1988, and although in 1994 the villages are likely to be connected to the PEA grid, it is anticipated that the micro-hydropower units will still be used, as they are likely to provide cheaper electricity [pc: Huay Somsuk].

The ATA has not been involved with any other hydropower projects since the completion of these schemes, however, they are presently considering implementing a new scheme in a nearby village.

EGAT

EGAT has constructed five micro-hydropower plants in response to the royal initiative to improve the economic situation of the hill-tribe peoples. It has also established a hybrid 20kW hydropower and 20kW photovoltaic grid connected demonstration system.

6.4.4. Mini-hydropower

By 1990, nineteen mini-hydropower schemes with a total installed capacity of 28.6MW had been commissioned within Thailand. As can be seen from figure 6.12, the majority of these have been developed by the NEA/DEA, whereas EGAT developed two schemes of 1.3MW each [EGAT, 1989], and the PEA a further three. A 'Masterplan' for mini-hydropower development which was completed for the NEA/DEA in 1988, investigated over 1000 sites, of which 192 were considered to be technically feasible.

Station	Province	Installed capacity (kW)	Commissioned	Operated by	Main purpose of installation
Bo Kaeo	Chiang Mai	200	1984	NEA/DEA	
Duson	Satoon	680	1990	NEA/DEA	Line stabilisation
Huai Mae Phong	Payao	1,040	1984	NEA/DEA	Multipurpose
Khlong Lam Plok	Trang	1,300	1989	NEA/DEA	Line stabilisation
Mae Hat	Chiang Mai	864	1988	NEA/DEA	Line stabilisation
Mae Kum Luang	Chiang Mai	3,200	1982	NEA/DEA	Replace diesel generator
Mae Mao	Chiang Mai	4,400	1988	NEA/DEA	Replace diesel generator
Mae Sa Nga	Mae Hongsorn	5,040	1988	NEA/DEA	Replace diesel generator
Mae Sap	Chiang Mai	1,360	1988	NEA/DEA	Delay transmission line project
Mae Tuen	Chiang Mai	250	1986	NEA/DEA	Delay transmission line project
Mae Sariang	Mae Hongsorn	1,200	1985	NEA/DEA	Replace diesel generator
Nam Kha Mun	Pitsanulok	1,020	1989	NEA/DEA	Line stabilisation & minimise losses
Nam Mae Sot	Tak	762	1989	NEA/DEA	Line stabilization
Pha Bong	Mae Hongsorn	935	1972	NEA/DEA	Replace diesel generator
Mae Chai	Chiang Mai	875	1985	PEA	Replace diesel generator
Mae Tien	Chiang Mai	1,912	1985	PEA	Line stabilisation and extension
Mae Ya	Chiang Mai	1,000	1990	PEA	
Ban Santi	Yala	1,300	1982	EGAT	
Huai Kum Dam	Chaiyaphum	1,300	1982	EGAT	

[Adapted from: Balfour Beatty, 1990]

FIGURE 6.12: Mini-hydropower sites completed up to 1990

The aims for the schemes are primarily to reduce the region's dependency upon diesel and to stabilise the PEA's distribution lines. Due to the extension of the PEA grid to many of the areas where these projects are situated, the economic benefits of these projects are not as great as initially anticipated by the NEA/DEA. Figures 6.13 and 6.14

Station	Installed capacity (kW)	Maximum output (kW)	Limitations
Pha Bong	935	200	Line limit
Mae Sa Nga	5,040	2,300	Line limit
Mae Hat	864	800	Capacity not fully utilised
Mae Kum Luang	3,200	1,400	Transformer failure
Mae Mao	4,400	2,400	Turbines at low head
Huai Mae Phong	1,040	910	OK
Mae Sap	1,360	-	Filling reservoir
Bo Kaed	200	50	Turbine problems
Mae Tuen	320	40	Turbine problems
Mae Sariang	1,200	600	Line limit
Nam Mae Sot	762	350	Turbine problems
Nam Kha Mun	1,020	1,000	OK
Khlong Lam Plok	1,300	-	Transformer failure

[Source: Balfour Beatty, 1990].

FIGURE 6.13: Output limitations of existing NEA/DEA mini-hydropower schemes

State of equipment	Capacity	
	(kW)	(%)
Equipment operating	10,050	46
Line limitations	3,857	18
Transformer failures	2,900	14
Capacity under utilised	2,664	12
Station maintenance	1,360	6
Turbine problems	810	4
	21,641	100

[Source: Balfour Beatty, 1990]

FIGURE 6.14: State of mini-hydropower equipment as of July 1990

show the limitations experienced by the NEA/DEA schemes as of July 1990. Presently, electricity from the NEA/DEA mini-hydropower schemes is sold to the PEA grid, but as the NEA/DEA is an implementing agency, and does not have a budget for scheme maintenance, the PEA have recently been asked to take over their ownership and operation. As substantial sums of money will be required to improve the output of many of the schemes, the PEA are undecided as to whether to undertake this responsibility. The civil work for most of the NEA/DEA sites is considered to be technically adequate, however, as most of the designs are scaled-down versions of larger schemes, they are also over-engineered [pc: Hartley].

Foreign aid has been available for the installation of the majority of the schemes. The PEA's mini-hydropower projects are a part of the Accelerated Rural Electrification programme, and aim to replace diesel-powered equipment where it is found to be economically advantageous. In conjunction with Norconsult of Norway and with grant funding from the Norwegian government, the PEA began their first project in 1980. This grant covered all equipment costs for two schemes, as well as providing for training of PEA staff in planning, design, operation and maintenance. The PEA were left with the responsibility for providing finance for the civil works.

After the completion of these schemes in 1985, three further aid funded projects were initiated and financed by the British Overseas Development Administration. The first of these schemes, the Mae Ya project, was completed in early 1990, whereas the other two are still under construction. There have been long delays in the construction phases of the three projects due initially to an acute shortage of cement in the country a few years ago and also due to the inability of the initial Thai contractor to produce the necessary site civil works designs. The three projects, of 1MW, 2MW and 2MW, will use turgo impulse turbines, the designs of which are such that parts will be interchangeable, thus reducing the number of spare parts required [SHP News, 1988]. Standardisation of the three sites has increased capital costs, but will reduce the cost of training, repair and maintenance.

6.4.5. Future plans

There is political commitment to electrify virtually all of the country's villages [Meridian Corporation]. The country's Seventh National Plan for the period from 1992 to 1996 details plans for a further nineteen mini-hydropower schemes with a total capacity of 44.5MW, with capacities ranging from 350kW to 4,500kW. This is as well as twelve schemes which are already under construction. Fourteen of the new schemes are

designated to be built by the PEA, which will be a substantial increase in their involvement with mini-hydro [NESDB, 1992 (b)].

As a part of these proposals, PEA engineers in conjunction with the engineering company Balfour Beatty of the United Kingdom have just completed feasibility studies for a further three mini-hydropower projects in the Northeast of the country. These are presently awaiting approval from the National Economic and Social Development Board, who will advise the Royal Thai government upon whether to obtain a £13 million (US$19.5 million) loan from the British Government for these three projects and several new sub-stations. If the approval is given, then the detailed design will be undertaken by Balfour Beatty in conjunction with PEA staff. It is anticipated that these projects will take between three and five years to complete. Until recently the PEA believed that they would only be constructing a further three or four projects at most over the next ten years. They considered that for future projects, private companies would be commissioned to undertake feasibility studies, as they did not consider it possible to keep PEA staff fully employed with mini-hydro work.

A 'Masterplan' study of the micro-hydropower resource potential around villages presently without electricity has been commissioned by the NEA/DEA. The 'Masterplan' will assess approximately 300 sites with potentials of up to 200kW and it is envisaged that up to 30 of these will proceed to a detailed site investigation. The majority of those sites which are eventually constructed are likely to be supplied with turbines manufactured by the Mining and Industrial Machine Workshop based in Chiang Mai. The NEA/DEA have been constructing on average between four to six micro-hydropower schemes per year, and this rate of construction is likely to continue into the near future. Seventeen micro-hydropower schemes are reported to have been under construction at the end of 1992 [NESDB, 1992 (b)].

The Mechanical Engineering Department at Chiang Mai University has made a proposal in conjunction with the German Appropriate Technology Exchange (GTZ-GATE) to undertake an assessment of potential micro-hydropower sites in the North. They are currently looking for funding for the project.

The People's Volunteer Weir programme has objectives of building 12,000 small weirs over 5 years, based upon villagers' traditional spirit of self-help [Prakob Wirojanagud, 1990]. It may in some cases be economically viable to develop a micro-hydropower scheme in conjunction with such schemes within villages without electricity.

Although the majority of lowland areas throughout the country are electrified, there is potentially a sizable market for low-head turbines for irrigation canals. Propeller turbines designed for a three metre head, and in the order of 20kW capacity would probably be the single greatest market [pc: Choke].

6.4.6. Requirements for micro-hydropower and mini-hydropower development

As the civil works are the most expensive items of a micro-hydropower scheme, reducing the costs of the schemes' civil works would have the greatest impact upon them becoming more economically viable. This is essential if they are to be used more extensively, now that the NEA/DEA have to rely more upon government funds rather than foreign aid [pc: Prida Wibulswas].

If the NESDB proposals for mini-hydropower development are to be fulfilled, then the PEA will need to train many more staff in the installation, operation and maintenance of schemes.

6.5. LOCAL MANUFACTURE OF HYDROPOWER EQUIPMENT

6.5.1. Introduction

In the hills to the North and West of the country locally made devices for harnessing power from local streams have been made for many decades. Since the late 1970's several organisations have manufactured metal turbines for micro-hydropower schemes, and some components for mini-hydropower schemes, however, only one company is still manufacturing this equipment.

6.5.2. Government policies towards local manufacture of hydropower equipment

The NEA/DEA, the government body responsible for micro-hydropower within Thailand during the 1980's, were eager to develop manufacturing capabilities within the country. Since the early 1980's there has been an evident policy for the NEA/DEA to buy Thai-made equipment wherever possible. NEA/DEA engineers has advised several Thai manufacturers as to how to adapt their products in order to be suitable for micro-hydropower developments, and in some cases the NEA/DEA has transferred the technological know-how to enable these companies to manufacture component parts. The Royal Thai Government allocates approximately US$400,000 per year in soft loans to manufacturers for the production of energy devices developed by the NEA/DEA.

The government is eager to attract foreign investment, in order to enable the manufacture of more engineering products within Thailand.

6.5.3. Acquisition of technological capabilities

Foreign investment is generally welcomed in Thailand. Promotional privileges for foreign investors include exemption from income tax for a period, no customs duties and no business tax on imported manufacturing machinery [UN, 1990 (a)]. Imports are freely allowed, with no import approval required. Virtually no customs duties or sales taxes are levied on exports, although duty is levied on many imported items, as can be seen from the table below.

Product	**Import Tax**
Turbines	30%
Regulators	30%
Generators	35%
Transformers	35%
Pumps	30%

[Customs Department, 1989].

The Department of Industrial Promotion and the Department of Industrial Works are both concerned with technology transfer, and the Technology Transfer Centre of Ministry of Science and Technology provides promotional services such as evaluating new technologies. The Thai Patent Act of 1979, protects only patents granted by the Thai Patent Office, whereas inventions already patented in other countries may not be patented in Thailand. A Copyright Act came into effect in 1978 [Ernst and Young, 1990]. Thailand is a signatory of GATT and as it has received IMF financing it is constrained from prohibiting imports other than in special categories. The ASEAN Preferential Trading Agreements, however, does provides a framework for preferential trading and trade liberalisation among member countries, and extension of tariff preferences [UN, 1990 (a)].

The first mini-hydropower and micro-hydropower schemes established in Thailand were set up on a turn-key basis, with all equipment being imported. Substitution with locally produced equipment started initially with the purchase and replication of an imported Chinese turbine/generator/governor set [Helling, 1986]. Following this, in the late 1970's, a crossflow turbine was designed from first principles by a Thai engineer, with the help of funding from the National Research Council of Thailand. No royalties or other fees needed to be paid and no licensing agreement was necessary, as the design was from

readily available data. The turbine was characterised by both high efficiency and durability, and was designed to facilitate manufacture of the runner, guide vanes and housing, at well-equipped Thai machine shops [Helling, 1986]. This design won an award for Engineering Excellence. In 1979, after one year in the laboratory and workshop, a 7.5kW crossflow turbine attached to a Chinese generator was installed at an isolated site for field testing. The success of the equipment has led to the Mining and Industrial Machine Workshop, based in Chiang Mai, being commissioned to manufacture over 25 crossflow turbines based upon NEA/DEA designs. They are presently the only manufacturers of turbines in the country with a regular production.

In the early 1980's a large commercial machine shop in Bangkok was commissioned to manufacture a 180kW turbine, whereas both the generator and the governor for the scheme were imported. It was initially hoped that this would further the Thai turbine manufacturing capabilities, with the aim of Thailand becoming exporters of turbines to the ASEAN region. A French company, Ateliers Bouvier, worked in conjunction with the NEA/DEA and the South East Asia Commercial and Engineering Company, implementing six power plants with twelve turbines. Both Francis and Pelton equipment were produced, ranging in capacity from 381 to 2550kW [WPDC, 1991 (b)]. The first contract involved virtually all of the mechanical and electrical equipment being imported. The French company transferred some of the manufacturing technology to the Thai company, principally due to the conditions of the contracts which stipulated that 50% of the equipment cost had to go to Thai manufacturers. The static components for the Francis turbines, which included spiral casing, draft tube, frame and guide vanes were manufactured in Thailand, with all of the design work done in France [NRECA, 1983]. For the Pelton turbines, only the runner and nozzles were supplied from France. Although no equipment is presently being made by the Thai company, Bouvier are now maintaining their presence in the country by having a maintenance and after-sales service contract for the sites [Etienne, 1990].

As part of the PEA programme to develop mini-hydropower schemes and absorb some of the necessary design and installation know-how, twenty PEA engineers spent five weeks in England visiting Gilkes, a manufacturer of turbines for small hydropower, in conjunction with the United Kingdom contractor Balfour Beatty. PEA engineers also received training in repair and maintenance for equipment of three schemes built by Balfour Beatty within Thailand, and were involved during the installation of the scheme. The cost of training was less than 2% of the total cost of the scheme [Chulapongs Chullakesa, 1991 (c)]. The designs were carried out at the PEA's offices, and whereas the average time to design each project was four months, which is longer than would be

expected by Balfour Beatty's project [Evans, 1990], this enabled much of the third scheme to be designed by the Thai engineers [Chulapongs Chullakesa, 1991 (c)].

A Thai NGO, the Appropriate Technology Association (ATA) have developed two micro-hydro schemes and manufactured their own equipment. The designs and manufacturing process were based upon the experience gained by one of their engineers on a visit to micro-hydropower equipment producing workshops and micro-hydropower sites in Nepal. The ATA turbines are crossflow, adapted from a GTZ-GATE design. The schemes have proved to be reliable, however, the ATA do not presently have any plans to produce any more machines due to lack of finance.

In 1981, after extensive research in the United Kingdom, the first three-phase ELC was field tested on site in Thailand. After the first year of trouble-free operation, a license agreement was negotiated between GP Electronics of the United Kingdom and the NEA/DEA to assemble the controller from kits. The designer produced a manual, including fault-finding techniques and assembly instructions for the kits which they supplied [Whitby, 1984]. With guidance from NEA/DEA engineers a local manufacturer has been able to improve on the durability of the product [Helling, 1986]. It is believed that all of the components can now be produced in Thailand [pc: Brown].

Throughout Thailand, on-the-job training is more prevalent than formal training programmes, and most employees in industry are trained in-house for specific jobs. Most of the large companies have design files, engineers and draftsmen [Pinij Srangsriwong, 1985], and the technological capabilities of the country's companies is comparable to that of the Newly Industrialised Countries of East and South-East Asia.

6.5.4. Turbines

Both crossflow and Pelton turbines have been manufactured within Thailand, however, no reaction turbines have been made. Of 35 NEA/DEA micro-hydropower schemes, 21 use crossflow turbines, and 9 pelton turbines.

Since the NEA commissioned a workshop to manufacture a micro-hydropower crossflow turbine in the late 1970's, locally manufactured equipment has been shown to be reliable and relatively cheap [Wiroth Wongseree, 1987]. Over 30 crossflow turbines have been produced by the Mining and Industrial Machine Workshop in Chiang Mai. Twelve Francis and Pelton turbines were produced in Bangkok, however, the producer is no longer manufacturing hydropower equipment. Several other organisations have produced

one or two turbines, some of which have been installed.

Project	Capacity (kW)	Turbine type	Turbine cost/kW (US$)	ELC cost/kW (US$)	Turbine, ELC and generator cost/kW (US$)
Pang An	10	Crossflow	360	240	720
Meo Khun Wang	10	Crossflow	240	240	600
Pang Bong	12	Pelton	110	207	433
Mae Loei	12	Crossflow	243	207	567
Khun Lao	12	Pelton	337	207	660
Mae Mae	12	Crossflow	277	207	600
Huai Nam Rin	15	Crossflow	200	173	480
Mae Saa	15	Pelton	200	173	480
Huai Moh	20	Pelton	156	144	400
Thung Lakhorn	35	Pelton	114	98	287
Mae Kampong	40	Pelton	75	91	202
Mae Hae	50	Crossflow	148	76	296
Huai Pui	50	Crossflow	44	76	192

[Source: Helling, 1986]

FIGURE 6.15: Equipment costs for ELC governed schemes commissioned between 1983 and 1986

Figure 6.15 shows the cost of Thai manufactured turbines. Locally made turbines are generally considered to be adequately designed [Brown], and although they are typically characterised by low efficiency [Sawad Hemkamol, 1990] the NEA/DEA consider them to be of acceptable standard for their micro-hydropower development programme.

Several methods of manufacture have been used to produce crossflow turbines in the country. The runners of the crossflow turbines produced by the Mining and Industrial Machine Workshop are made from stainless steel, with hand shaped blades, and graphite shaft seals [Brown]. The two turbines of 7kW and 10kW capacity produced by the ATA were fabricated by welding steel tubing to steel supporting discs [ATA, 1987]. The Sangtawee Engineering Co. Ltd/Hiap Thai Machinery Co., Ltd, could mass produce equipment using their stamping press for certain parts, if the demand for equipment was great enough [Pinij Srangsriwong, 1985].

Component parts for several mini-hydropower turbines were also manufactured in Thailand, however, all equipment is presently being imported. Figure 6.16 shows the origin of most of the Thai mini-hydropower equipment. Pelton runners, stainless steel parts including spear valves, and bearing sub-assemblies have in the past been produced in Bangkok [Helling, 1986]. The runners were made from stainless steel buckets, which were cast then dressed by hand and bolted on to the hub. One apparent design flaw was

the lack of individual jet gate valves, resulting in an inability to regulate the flow of water [Brown]. The static components for mini-hydropower Francis turbines, which included spiral casing, draft tube, frame and guide vanes have all been produced in Bangkok [Etienne, 1990].

Station	Installed capacity (kW)	Turbine type	Turbine origin	Generator origin
Bo Kaeo	200	Pelton	Thailand	Thailand
Duson	680	-	-	-
Huai Mae Phong	1,040	Pelton	France	France
Khlong Lam Plok	1,300	Pelton	France	US
Mae Hat	864	Pelton	France	Thailand
Mae Kum Luang	3,200	Francis	Japan	Japan
Mae Mao	4,400	Francis	France/Thailand	Germany
Mae Sa Nga	5,040	-	France	Germany
Mae Sap	1,360	Francis	China	China
Mae Tuen	250	Crossflow	Thailand	Thailand
Mae Sariang	1,200	Francis	Japan	Japan
Nam Kha Mun	1,020	Pelton	France/Thailand	US
Nam Mae Sot	762	Francis	France/Thailand	US
Pha Bong	935	Francis	Austria	-
Mae Tien	1,910	Francis	Norway	Norway
Mae Chai	875	Francis	Norway	Norway
Mae Ya	1,000	Turgo	Britain	Britain

[Source: Balfour Beatty, 1990]

FIGURE 6.16: Source of mini-hydropower equipment installed within Thailand

Other organisations have the skills and machinery to produce Pelton turbines, with runners of up to 2m in diameter. Larger units could be built if the runner were to be imported. The engineers at one foundry consider that they are able to cast solid one piece Pelton runners from stainless steel, and several other organisations can readily cast individual buckets [Pinij Srangsriwong, 1985].

As yet no complete reaction turbine has been designed or built in Thailand, and indeed they are not likely to be required for the current NEA/DEA's micro-hydropower programme. Centrifugal pumps are manufactured by several organisations, and research into reverse pumps-as-turbines is being undertaken at the Appropriate Technology

Research Unit at Chulalongkorn University, Bangkok. One company is considering whether to produce small propeller turbines [Pinij Srangsriwong, 1985].

6.5.5. Generators

Synchronous generators of rated capacities up to 500kW are manufactured in Thailand. Induction generators have also been produced, and several organisations are involved in the rebuilding of secondhand generators and motors [Pinij Srangsriwong, 1985].

In the early 1980's a local generator manufacturer was helped by NEA engineers to improve the durability of the generators it was producing, for use in conjunction with hydropower schemes. Improvement of the bearing assemblies enabled the generators to cope with the over-speed stresses which can be encountered when used for hydropower schemes [Helling, 1986]. Thai generators are considered to have superior operating characteristics and repairability features over the Chinese equipment [USAID, 1982] which had previously been used by the NEA/DEA. At least one generator manufacturer in Bangkok produces generators to standards parallel to those in the United States of America.

6.5.6. Governors

Governors for micro-hydropower schemes were initially a large proportion of the cost of equipment in Thailand. In one case, the cost of an imported governor was as much as the combined cost of the generator and turbine [Whitby, 1984]. Thus there has been a great deal of interest in obtaining a low cost, reliable governor, and in 1980 a prototype ELC was offered by the Intermediate Technology Development Group (ITDG) from the United Kingdom. This prototype was installed at the Khun Kong 10kW project [Helling, 1986], and after a period of trouble-free operation the NEA/DEA negotiated to assemble the ELCs at their own Electricians Training Centre workshop. Since the early 1980's most micro-hydropower schemes have utilised ELCs, of which over twenty have been produced. The power supply and operating components for the ELC are fabricated locally, and the main control circuit boards imported from the United Kingdom [Helling, 1986]. It is estimated that two men are able to assemble three kits per week at the workshop, however, only a few per year are required [Whitby, 1984]. Initially there were problems with the fabrication of the water heating ballast tanks, however, the ELCs have subsequently been reportedly operating trouble-free [Brown].

An ELC was also designed and produced by the ATA, with the experience gained by one of their staff visiting sites and manufacturers in Nepal [ATA, 1987].

The mini-hydropower schemes in Thailand have used mechanical-hydraulic and electronic-hydraulic governors, virtually all of which have been imported. In 1986 after considerable effort, the first Thai-made hydraulic governor was installed, although they proved to be difficult for local workshops to replicate reliably [Helling, 1986]. Most governors used in Thailand are produced by Woodward of the United States of America, or are of Chinese origin.

The Mining and Industrial Machine Workshop is also capable of producing mechanical governors, however, presently all of the machines which they produce are governed by ELCs made by the NEA/DEA.

6.5.7. Family-hydropower equipment

Whereas many small turbines have been made, no Family-hydropower units have been produced within Thailand. Many workshops, as well as larger organisations, both within Bangkok and many provincial towns, have the skills and equipment to produce Family-hydropower equipment, if the demand was large enough to warrant production.

6.5.8. Other equipment

Almost all of the other equipment required for micro-hydropower schemes with capacities below 100kW can be produced within Thailand. Virtually all of the equipment for mini-hydropower and larger schemes is presently imported.

Transformers are produced by several organisations in Thailand. Ekarat Engineering Co. Ltd. have been producing transformers for ten years. In 1992 they sold over 7,000 units rated between 5 and 100,000kVA, both within Thailand and throughout South-East Asia. They obtained the product designs via licensing agreements and joint ventures in conjunction with Israeli, German and Japanese companies. They now produce some of their own designs, modifying the original designs to account for different raw materials, different manufacturing methods and the different requirements of the buyers in South-East Asia [pc: Ekarat Engineering]. Other producers of transformers include Thai Maxwell and Inter Trafo Co. Ltd.

Low carbon steel penstock have also been produced by several organisations, and many more workshops in all parts of the country have the capabilities to produce them. Gate and butterfly valves are made, the largest being up to two metres in diameter [Pinij Srangsriwong, 1985]. Speed-increasing gears could be produced within Thailand if the demand was large enough [USAID, 1982]. Steel plates for such products as fly-wheels are imported, as is most steel and iron [Pinij Srangsriwong, 1985].

The solenoid valve, operating valve, safety devices, electrical components, gauges, pumps and motors for hydraulic control systems are all imported and assembled in Thailand [Pinij Srangsriwong, 1985]. Switchgear and control panels are assembled within Thailand, however, most of the components are imported. Kilowatt-hour meters and capacitors are produced by the Oriental Electric Industry Co. Ltd., in Bangkok. There are many companies which produce electronic circuitry, printed circuit boards and electronic devices.

Because of the problems of deforestation, distribution line poles cannot be made from timber. Concrete poles are therefore produced in Thailand.

6.5.9. Assessment of companies involved in manufacture of hydropower equipment

Several companies have manufactured micro-hydropower turbines and associated equipment, and one has manufactured turbine embedded components for larger turbines. Only one of these is presently producing turbines on a regular basis. A description of those organisations with the greatest involvement is provided below.

Mining and Industrial Machine Workshop, Chiang Mai

The Mining and Industrial Machine Shop in Chiang Mai has been manufacturing turbines for sixteen years and is now the only company in the country presently producing turbines. So far they have fabricated about 30 micro-hydropower machines with capacities up to 60kW, and heads above 15m, and they are capable of producing equipment of up to 100kW capacity [pc: Choke]. They produce crossflow turbines, including runners, turbine casings, flywheels and generator bases. It takes the company approximately 45 days to produce a set, and the eleven people employed by the company are capable of producing twenty sets per year if required. A 40kW machine designed for a 50m head would cost approximately 370,000 Baht (US$14,800) including turbine, turbine and generator mountings, and flywheel [pc: Choke]. This price compares favourably with those on the international market and with locally manufactured prices,

as shown in figure 2.5. Field tests have shown the crossflow runner efficiency to be approximately 75%. Figure 6.17 shows a 40kW crossflow unit produced by the workshop.

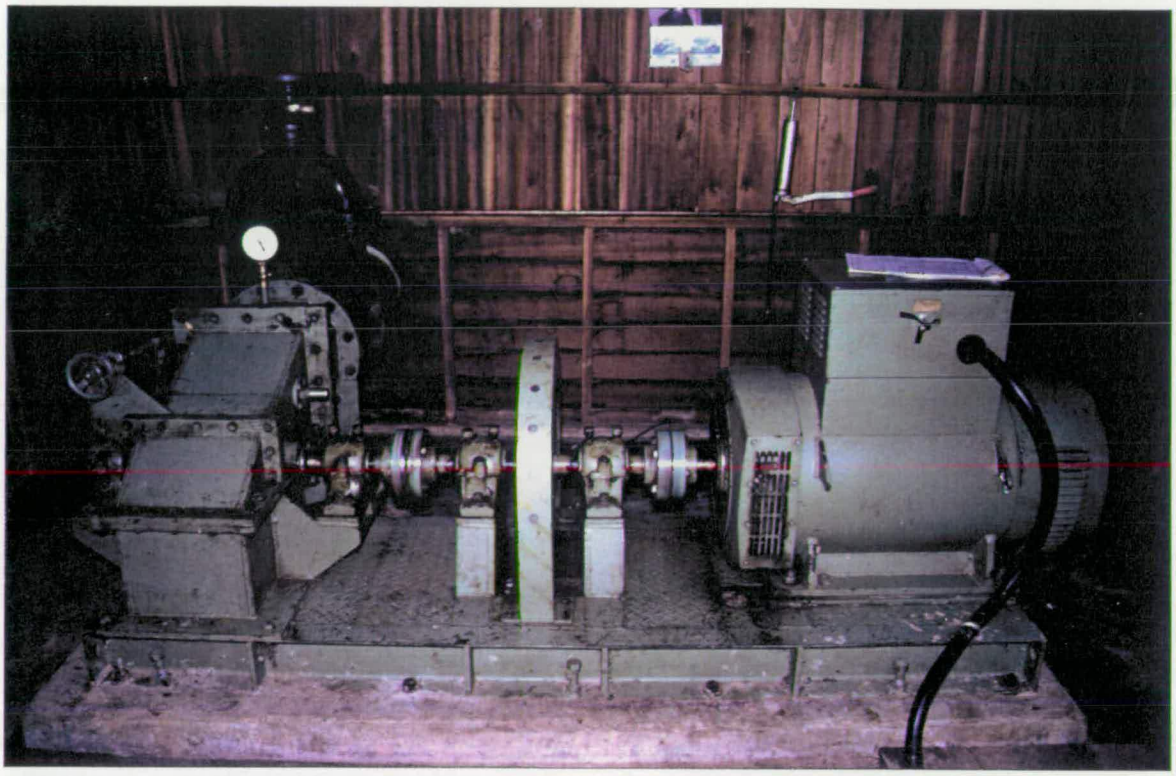


FIGURE 6.17: A 40kW crossflow turbine unit produced by the Mining and Industrial Machining Workshop, and installed at Pang Hai, Chiang Mai province

The company has also manufactured Pelton turbines, steel penstock, mechanical governors, hydraulic rams, gate valves and sluice gates [pc: Choke]. The equipment they produce is designed by the NEA/DEA for their own micro-hydropower developments. So far the company has manufactured exclusively for the NEA/DEA, although they have received enquiries from both Lao PDR and Myanmar.

Pornpat, Bangkok

The Pornpat company, with its sister organisation the South East Asia Commercial and Engineering company, in association with the Lane and Bowler Co. Ltd., used to manufacture micro-hydropower turbines and components, and also component parts for larger equipment in conjunction with Ateliers Bouvier of France [Etienne, 1990]. In the early 1980's they were requested by the NEA/DEA to help develop turbine

manufacturing capabilities with the aim of becoming exporters of the equipment to the ASEAN region. Pornpat is no longer manufacturing hydropower equipment, but is still involved in the installation and contracting for mini-hydropower schemes and is the main contractor for several of the NEA/DEA's schemes.

The static components for the Francis turbines, which included spiral casing, draft tube, frame and guide vanes [Helling, 1986], and all parts of the Pelton turbines, except for the runners and nozzles were manufactured here [Etienne, 1990]. They also assembled and tested the locally manufactured and imported equipment. The company also produces gate valves and pumps [Brown].

The organisation is no longer interested in manufacturing hydropower equipment as they consider the market within Thailand to be too small, with so few orders for equipment that they do not feel able to employ engineers and dedicate working space on a continual basis. Now they import everything, usually from Ateliers Bouvier (France), or from China, and their engineers work in conjunction with the representatives from the respective companies during the installation and commissioning stages of the projects [pc: Preecha].

PAT, Bangkok

The charitable company Promotion of Appropriate Technology, a sister organisation to the Appropriate Technology Association based in Bangkok, has produced two micro-hydropower turbines, which were installed in two villages near to Chiang Mai. These crossflow turbines of 7kW and 10kW capacity were fabricated by welding steel tubing to steel supporting discs. The designer of the equipment had visited Nepal to obtain ideas concerning design and manufacture of equipment. The first set took two months to fabricate, however, they consider that two weeks would be sufficient if demand rose.

They have also manufactured two ELCs, the design for which was an adaptation of the design used in Nepal, obtained by copying the Nepalese equipment.

University of Chiang Mai, Chiang Mai

The Department of Electrical Engineering at the University of Chiang Mai has produced several very small crossflow turbines which could be used for battery charging, or for water pumping. Only prototype units have been made to date, and there are presently no definite plans to produce more.

Other organisations

Several companies in the country have the capabilities to handle design, manufacture, civil work construction and installation for micro-hydropower equipment. Several provincial workshops have produced crossflow or Pelton turbines, to their own or government agency designs, and in some cases by copying existing equipment [Pinij Srangsriwong, 1985]. A number of foundries are able to cast and machine micro-hydropower components, and there are many small machine shops both within Bangkok, and other cities and towns, which could fabricate crossflow equipment with the right advice. Die casting and gravity casting facilities are available, as are induction and arc furnaces. The following organisations have been surveyed for their capacity to produce hydropower equipment [Pinij Srangsriwong, 1985]:

- Anusarn Co. of Chiang Mai have manufactured one crossflow unit and a Pelton unit for their own study, although their main line of work is with the manufacture of agricultural cultivators;

- Kor Thapae Ltd., Bangkok, has manufactured a 0.5kW Pelton turbine/generator set;

- Bamroongraj Workshop in Chiang Mai have adequate machine tools and skills to produce crossflow units;

- Sangtawee Engineering Co. Ltd./Hiap Thai Machinery Co. Ltd. could manufacture crossflow turbines in quantity if they considered the market to be large enough;

- Sathorn Works Co. Ltd. could produce Pelton buckets with their two 500kg induction furnaces using the lost wax process;

- Burapa Steel Co. Ltd. consider themselves capable of pouring a stainless steel Pelton wheel in one piece;

There are several other workshops which have two metre diameter lathes and other machinery necessary to produce Pelton runners of up to 500kW capacity.

6.5.10. Test facilities

The NEA/DEA have a hydraulic test laboratory, and are able to test various types of turbines, including pumps-as-turbines. None of the organisations which have

manufactured turbines have hydraulic test facilities.

6.5.11. Assessment of the local manufacturing capabilities

All equipment for crossflow schemes between 1kW and 100kW can be produced in Thailand, except for some switchgear equipment. At present this market is adequately supplied by the Mining and Industrial Workshop. Only impulse turbines, particularly crossflow, have been produced, whereas no reaction turbines, either propeller or Francis have been made. Virtually all mini-hydropower equipment is imported from China, Britain, France and Norway, however, some component parts of Francis and Pelton turbines have been produced in Thailand in the past.

Presently, crossflow turbines are produced on a site-specific basis by one company in Chiang Mai. Chiang Mai is well situated for the majority of NEA/DEA implemented sites, and manufacturing costs are lower there than in Bangkok. Equipment is cheap in comparison to that which is internationally available, and it has proved to be adequately reliable for the NEA/DEA's programme. Costs could be further reduced if equipment was to be mass produced, however, as there has not been any effort made to assess the full market potential, this is not considered to be worthwhile. Many companies can produce the components for crossflow or Pelton turbines.

The turbines and ELCs which are locally made have reduced equipment costs to half that of imported equipment [UN, 1988]. Turbine designs have been based upon theoretical information and not upon model tested data. This is likely to lead to turbines of lower efficiency and susceptible to greater cavitation than if test data was used to modify the basic designs [Pinij Srangsriwong, 1985]. The efficiency of the crossflow turbines has improved such that the equipment has been reliable and adequate for the NEA/DEA's micro-hydropower programme. Some scheme designs used in Thailand point to the likelihood of standardisation of design, or else a lack of technical design understanding. For example, the use of fly-wheels with ELCs is common even though they are not necessary.

The market potential for micro-hydropower and mini-hydropower is not well defined. Although several large organisations are able to handle all the requirements for micro-hydropower scheme development, few of these are set up for one-off manufacture. Thus many of these organisations have not been interested in manufacturing hydropower equipment, and would only be so if mass production were practical and there was sufficient demand.

6.5.12. Requirements for local manufacture

There is likely to be a market for medium head Family-hydropower units in the highland areas of the North. Transfer from Vietnam or China of the technology required to produce cheap, reliable Family-hydropower units, including battery charger and long life battery would provide those families which live in isolated areas, far from the grid, an opportunity to obtain a supply. The components could be marketed in an easy to use, and easy to install kit suitable for use by villagers and households presently without electricity in the isolated highland regions of the country.

A more efficient crossflow design could be developed, however, it is important to keep the cost of the equipment low. There are promising export possibilities to neighbouring countries for low cost crossflow equipment, and ELCs.

6.6. CHAPTER SUMMARY

Thailand has developed many mini-hydropower and micro-hydropower projects and has gained considerable experience in this field. It is generally considered that the need for micro-hydropower developments is diminishing in Thailand, as the local and national grid extend. This view, however, does not take into account the remote highland communities which so far have not received an electrical supply, and due to the remoteness of these communities micro-hydropower or mini-hydropower will often prove to be the least-cost option. Approximately 1,200 villages, with an average of 100 households per village, are likely to remain without an electricity supply when the present PEA rural electrification programme is completed. There is political commitment to electrify virtually all of the country's villages, and there is a willingness by most villagers to pay for small amounts of power.

All of the equipment for micro-hydropower schemes with capacities below 100kW can be produced within Thailand. Virtually all of the equipment for mini-hydropower and larger schemes is presently imported, and it appears that this is unlikely to change in the near future. The crossflow micro-hydropower units presently being built in Thailand have proved to be reliable and relatively cheap.

The schemes established in Thailand have been expensive due to the often excessive civil works. There is a relatively well coordinated infrastructure for micro-hydropower development, with good provisions being made for maintenance and repair.

CHAPTER SEVEN: ASSESSMENT AND RECOMMENDATIONS

7.1. COMPARISON OF EXPERIENCES BETWEEN THE THREE COUNTRIES

7.1.1. Introduction

It is evident from the preceding chapters that whereas there is demand for mini- and micro-hydropower development in each of the three countries under study, the circumstances prevailing within each country are significantly different. Figure 7.1 compares the basic conditions which characterise the three countries.

	Vietnam	Lao PDR	Thailand
Area (km^2)	329,000	236,800	513,000
Population	64.4 million	4.1 million	56.3 million
Percentage of population with electricity	< 20%	< 5%	74%
Percentage of rural population with electricity	13.9%	1.6%	72%
Total hydropower potential (MW)	18,000MW	20,000MW	7,000MW
Small-scale hydropower installed capacity (MW)*	30MW	3MW	3MW

*[Source: WPDC, 1991 (a)]

FIGURE 7.1: Comparison of the basic conditions in the three countries under study (1990)

The terrain found throughout much of northern and central Vietnam, northern Thailand and virtually all of the Lao PDR is hilly, and is suitable for mini- and micro-hydropower development. Only a small percentage of rural households within Vietnam and the Lao PDR have access to an electricity supply, whereas in Thailand, where there has been major investment in the rural electrification network since the early 1970's, the majority of rural people do have a supply. Rural incomes are particularly low within Vietnam, the Lao PDR, and in the Northeast and some hilly regions of northern Thailand. The

exploitable hydropower potential is greatest within these regions and thus represents an important resource to these areas.

7.1.2. Experience with local manufacture

Figure 7.2 summarises the manufacturing capabilities of each country. In the Lao PDR some local manufacture of equipment has taken place, but as yet this has not been firmly established, whereas in both Vietnam and Thailand manufacturing organisations are successfully producing equipment on a regular and ongoing basis.

	Vietnam	Lao PDR	Thailand
Turbines:			
Crossflow	5kW - 600kW	5kW - 40kW	5kW - 100kW
Pelton	20kW - 800kW	NO	Not at present
Francis	30kW - 2.1MW	NO	NO
Kaplan	5kW - 1MW	NO	NO
Family-hydropower	YES	NO	NO
Generators	Up to 400kW	NO	Up to 500kW
Governors:			
ELC	NO	NO	YES
Hydraulic	YES	NO	Not at present
Transformers	Up to 25,000kVA	NO	Up to 100,000kVA
Penstock	YES	YES	YES

FIGURE 7.2: Comparison of local manufacturing capabilities of the three countries under study

Vietnam presently has design and manufacturing capabilities for turbines ranging from 200W to 2.1MW, with Francis, Kaplan, crossflow, Pelton and propeller turbines having been produced. Although crossflow turbines are generally considered to be the easiest turbine to fabricate, the Vietnamese manufacturers have focused upon the production of Francis machines for medium-head sites. All other equipment required for a small-scale hydropower project has also been produced in the country.

Although the cheapest crossflow equipment has been produced in the Lao PDR, this equipment is the least efficient and least reliable of the equipment produced in the region.

So far ELCs are only being produced in Thailand, although they would be of benefit to all three countries. Generators are produced both in Vietnam and Thailand, however, the Vietnamese mainly use renovated generators for their hydropower schemes.

Small companies (having fewer than 30 employees) within both Vietnam and Thailand continue to produced turbines on a regular basis, whereas all larger companies which have been involved with turbine manufacture have now ceased turbine production. Government or electricity utility support was provided in the early stages of initiating every turbine production facility which became successful. Encouragement of local manufacture in Thailand has resulted in local design and fabrication capabilities for crossflow turbines with capacities up to 100kW.

7.1.3. Experience with transferring technology

Both Thailand and Vietnam have good micro-hydropower turbine manufacturing capabilities, the technology having been acquired by Thailand via in-country design and visits to developments in China, and in Vietnam mainly by copying equipment from abroad. In Vietnam, little formal technology transfer has taken place, principally due to the scarcity of foreign capital.

In Thailand the crossflow turbine was designed from first principles by the NEA/DEA, which disseminated the technology to a private company. Attempts at establishing a manufacturing base for mini-hydropower via a joint venture agreement with a French company did not succeed, as withdrawal by the French organisation resulted in the cessation of production. Transfer of the know-how required for scheme design, operation and maintenance has, however, been transferred successfully, with both the PEA and the NEA/DEA engineers having absorbed many of the skills necessary to perform these tasks. Operation and maintenance skills have been disseminated to key community members of village communities by NEA/DEA staff. The transfer of ELC technology has been successful as the equipment is now assembled within the country following an effective technology transfer programme, and all the necessary components can be produced within Thailand, and the equipment designed by NEA/DEA staff.

In the Lao PDR very little training or formal technology transfer has been undertaken, and very little dissemination of the technology has occurred other than operation and

basic maintenance know-how disseminated to users of the foreign built micro-hydropower schemes. Imports of micro-hydropower equipment by aid agencies has done little to transfer the technology to the country. Several crossflow turbines have been produced with the aid of published designs, which has only been partially effective in establishing the technology within the country.

7.1.4. Experience with mini- and micro-hydropower development

Figure 7.1 compares the level of rural electrification and the level of mini- and micro-hydropower development within the three countries. The market for future developments in each of the three countries will be discussed in sections 7.2.1, 7.3.1 and 7.4.1, for Vietnam, the Lao PDR and Thailand respectively. Throughout the region rural incomes are low, and virtually all mini- and micro-hydropower hydropower schemes have been funded either by the electricity utilities, NGOs, or governments. Family-hydropower equipment on the other hand has been purchased by private individuals within the Lao PDR and Vietnam, even within relatively poor areas.

The Thai government has invested considerably in rural electrification, which has included some small-scale hydropower developments, whereas funds have been considerably more restricted within both Vietnam and the Lao PDR. In order to reduce costs, local labour and local materials have been used in the construction of many schemes. In general, the schemes established in Thailand have been more expensive than those built in Vietnam and the Lao PDR, principally due to higher civil work costs.

Effective civil work construction capabilities are available within both Vietnam and Thailand, but less so in the Lao PDR. Village electricity cooperatives have worked well in Thailand, encouraging effective management, operation and maintenance of the schemes. These have been backed by effective provisions for maintenance and repair, and this has had a positive effect upon the availability of the schemes. At present there is a lack of infrastructural support in both Vietnam and the Lao PDR, and this has been partly to blame for the high percentage of schemes in disrepair, particularly in Vietnam.

Manual governing of micro-hydropower schemes has been a burden on some villages in both the Lao PDR and Vietnam, due to the requirement of having an operator present at the powerhouse at all times of operation. The use of ELCs in Thailand has provided a relatively cheap and reliable form of governing, avoiding the need for an operator being required at all times.

7.2. STRATEGIES FOR THE FUTURE: VIETNAM

7.2.1. Markets and demand

As has been shown in chapter 4, over 400 small-scale hydropower schemes have been established in Vietnam, however half these are not in operation, and are thus in need of renovation. At many of these sites the turbines will need to be replaced, providing a large market for equipment manufacturers, in addition to the market for new schemes. There are estimated to be approximately 2,500 new sites of capacity up to 100kW, and a further 500 sites of potential capacities between 100kW and 10MW. Public investment and foreign funding of mini-hydropower schemes is set to rise dramatically, and the Vietnamese Prime Minister has expressed a desire to construct up to 200 schemes with capacities in the region of 1MW each. Investment is expected to come both from international loans, and foreign investment via turn-key or BOT contracts for mini-hydropower scheme development, and joint venture agreements for equipment manufacture. Financial return at a rate comparable to the cost presently being paid by the electricity utilities for electricity from diesel generation would interest foreign investors, and such investment would aid those provinces without sufficient funds to develop independently their rural electrification network. Investment into micro-hydropower schemes is unlikely to be made, and these are most likely to be developed with funds from provincial government, NGOs, or as part of a loan package requested by the central government for rural electrification. The United States economic embargo of the country has prevented the government from obtaining funds from most foreign sources, but with restrictions having recently been lifted, new trade agreements will soon become available enabled by the inflow of funds, and in turn these agreements will attract more funds from investors.

The inadequacies of much of the equipment produced in the 1980's has created a poor reputation for Vietnamese equipment, and there has recently been little enthusiasm to purchase Vietnamese-made turbines. With the low cost of reliable and efficient Vietnamese equipment currently available, the demand for locally produced micro-hydropower equipment is likely to rise again. Foreign involvement in equipment manufacture is also likely to provide an opportunity for the export of powerhouse equipment from Vietnam.

The increasing cost of fuelwood and the price rural people are beginning to pay for kerosene, or small amounts of electricity from batteries, shows that there is a willingness and capability to pay for an energy supply. With its large population, the majority of

whom are presently without electricity, there is a large market for all sizes of hydropower schemes within Vietnam, from Family-hydropower through to micro-hydropower for isolated schemes, to mini-hydropower for local grid developments. With an average annual income of a typical Vietnamese farmer being between US$150 and US$220, and savings tending to be low, low capital cost will remain the overriding factor affecting small-scale hydropower development in the country.

Family-hydropower units have become popular due to their low cost, ease of installation and light weight.

7.2.2. Hydropower development

There are many well trained engineers in the country, and the majority of sites have been constructed without direct foreign assistance. As has been described in chapter 4, the failure of a large proportion of sites has been caused by the inappropriate siting of reaction turbines, compounded by the high silt content of many of the country's rivers and the inadequate use of de-silting mechanisms. In order to create a sustainable environment for small-scale hydropower development in Vietnam, the following approach is recommended.

- The renovation of a small proportion of the schemes in disrepair should take place, along with the establishment of new schemes at the present rate of development. This will enable the build up of infrastructural support to take place, and lessons to be learnt from the earlier schemes, before major new investments are made.

- In conjunction with this it will be important to build up a regional, or in some cases provincial, repair and maintenance structure to support these schemes. A support team in the regions of the North, Central and South will be the minimum required. These could be initiated by the Institute of Energy, and funded from a tax placed upon the tariffs paid for electricity from the schemes.

- The building-up of local manufacturing capabilities should also be taking place during this time, as will be described in more detail in section 7.2.3.

- Once some of the schemes have been repaired and once the support infrastructure is in operation, development of a new 200 scheme programme as desired by the Vietnamese premier can then be initiated, using locally manufactured equipment.

Other aspects which will be important for programme planners to consider include the following.

- There will be a need for credit packages to be provided to rural consumers requiring electricity connections to their homes. These would best be supplied by extending the work of existing credit cooperatives.

- As locally managed micro-hydropower schemes have been seen to be in better condition than centrally managed schemes, it is considered that micro-hydropower schemes should continue to be operated by local operators with automatic governing being introduced, whereas utilities should continue to operate mini-hydropower schemes.

- New plant needs to be automatic, reliable and easy to operate.

- More care needs to be taken concerning the siting of reaction turbines to avoid excessive cavitation.

- More attention needs to be placed on measuring water flow rate characteristics and relating these to the results of desk-based hydrological studies, as opposed to the over reliance upon solely desk-based data.

- More focus needs to be placed on productive end use promotion and the financial sustainability of schemes.

- Rice milling is a major activity throughout the region. As micro-hydropower schemes can be used to power a rice mill directly, thus eliminating the losses of, or even need for a generator, it is recommended that this option should be properly considered with every implementation of a micro-hydropower scheme.

- Current cut-off switches could be used at schemes where excessive loading of the supply is significantly affecting operation. Their expense will prevent them from being used in all cases.

- In provinces where many Family-hydropower units are being installed (particularly in the North), an organisation established by the provincial government should be established to provide advice and support for the installation of equipment. This will help to ensure that maximum benefit is gained from these units.

7.2.3. Local manufacture and technology transfer requirements

Due to the large market for hydropower equipment, both local organisations and foreign companies should be able to invest profitably in a Vietnamese manufacturing base. Although manufacturing capabilities already exist for Francis, Kaplan, Pelton, propeller and crossflow turbines, as well as electronic governors and generators, future funding for an expansion of the manufacturing industry is likely to come from foreign companies. Several foreign companies have become interested in the Vietnamese market, and joint ventures with a Vietnamese company is likely to be the most sure way to enter that market. As powerhouse equipment in Vietnam is cheaper than equipment produced in Western countries, foreign investors will be hoping to produce cheap, low cost equipment for both the Vietnamese and possibly foreign markets, particularly in South-East Asia.

Although the skills required for the manufacture of small-scale hydropower equipment are present within Vietnam, there are several technology transfer requirements, including:

- obtaining improved Kaplan and Francis runner profiles to increase turbine efficiency;
- developing a cost effective governor for schemes below 100kW;
- acquiring the skills and equipment to mass produce generators;
- training for scheme designers in the effects of cavitation on reaction turbines, and design for the parallel operation of two turbines, which have both been problematic within Vietnam;
- creating a test and measurement facility for testing prototypes and assessing the quality of manufactured equipment.

The transfer of these technologies could each be transferred to existing companies in Vietnam such as the Hydro Electric Research Centre, or the Electrical Equipment Designing Enterprise, both in Hanoi, and funded by foreign companies interested in gaining a Vietnamese manufacturing partner. It is recommended that joint venture agreements be entered into, whereby the foreign company provides funds for the expansion of local capabilities and up-grading of manufacturing equipment and transfer of technology as described above. Vietnamese organisations have become very skilled at absorbing foreign technology, especially as foreign capital is so scarce. In exchange, a

foreign investor will benefit from a share of future sales of equipment and from access to the Vietnamese market. It is considered that the usual reluctance to transferring technology (which has been described in section 3.6.2) will be off-set by the size of the Vietnamese market.

It is recommended that ELCs be produced within Vietnam as this would ease the burden of manual governing schemes below 50kW. They are not necessary for Family-hydropower equipment. ELC technology could be supplied by a NGO, such as the Intermediate Technology Development Group, which has been involved in transferring the technology to several developing countries. The RERC and the governor organisation are considered to be the most suitable Vietnamese organisations to become involved with this. Training in both ELC manufacture and use is needed, as is the need to disseminate the knowledge of the ELC to all organisations involved with micro-hydropower implementation, and not solely to the manufacturers of the equipment. Induction generators could be produced by several companies, including the Dong Anh Electrical Equipment Factory in Hanoi.

The importance of the following factors does not appear to be fully appreciated by project planners and designers, and it is recommended that they be fully investigated for each new project:

- using actual hydrological data, as opposed to relying solely on desk based analysis;
- promoting productive end uses for the schemes;
- assessing the economic feasibility of a scheme and demand for electricity before implementation.

The RERC could become involved in technology transfer of Family-hydropower equipment manufacture to other countries, such as the Lao PDR, if they so desired.

7.2.4. Additional recommendations to electricity utilities and the Vietnamese government

In order to begin the programme of renovation and construction of new sites with the help of foreign investment, the financial and legal environment will need to be seen to encourage foreign investment. It is considered that foreign investors will be eager to build private schemes with capacities in the mini-hydropower range and above, if

assurance of payment for the electricity produced is underwritten either in law or in some other enforceable way. In order to create this, the following government initiatives would be advantageous:

- the constitution of a law which allows for the private generation of electricity and the private development of small-scale hydropower schemes;

- the constitution of a law which requires electricity utilities to buy electricity at a similar price to the cost of electricity produced at their existing plant.

Vietnam is currently able to manufacture the majority of powerhouse equipment for schemes up to 1.5MW, as has been shown in section 4.5, however, more investment in its own manufacturing base is required. Both foreign investors and local organisations will be more willing to make investments in manufacturing equipment if the policy of the electricity utilities is to buy locally made equipment in preference to foreign equipment. The establishment of a 'Masterplan' for the development of a mini- and micro-hydropower schemes in the North, Central and hill regions of the South will also promote the development of a stronger local manufacturing capability based on a secure knowledge of a large future market.

Based on the facts that domestic coal and electricity prices are subsidised, and that there is still a large percentage of the rural population who are not accustomed to paying for energy commodities, there is a justifiable case for small-scale hydropower developments being subsidised. At present there is little or no cross-subsidy of electricity tariffs from urban to rural areas as is the case in many other countries, including Thailand. In fact, the tariff is often higher in rural areas in accordance with the higher losses in these areas, and higher transmission costs.

The failure of so many small-scale mini- and micro-hydropower schemes has been compounded by the lack of the financial provisions to pay for project repair, and a lack of adequate infrastructure to ensure effective maintenance cover. Both electricity utilities and government agencies need to establish effective supporting infrastructure to avoid wasting investment in projects which will function for only a short period of time. It will be important to create a repair infrastructure for both utility and private sites, perhaps funded by taking a tax on the electricity sold, so that effective repair and maintenance can be achieved, as has been recommended in section 7.2.2.

It is important that implementing organisations realise the importance of using automatic governing systems even for micro-hydropower schemes in order to avoid putting the burden of manual governing onto the recipient community, which has in some cases itself led to some recipient communities not providing the necessary supervision, maintenance, or funds for repair. Implementing organisations and electricity utilities also need to realise the importance of demand analysis before construction, and of emphasising the promotion of productive end use after commissioning.

Provincial government offices should be encouraged to provide installation support and advice for Family-hydropower installations, and to define their policy on the subsidy of Family-hydropower units.

7.3. STRATEGIES FOR THE FUTURE: LAO PDR

7.3.1. Markets and demand

With less than 2% of the rural population of the Lao PDR having access to electricity, and the majority of rural villages being dispersed throughout areas of hilly terrain with high levels of rainfall, small-scale hydropower schemes are frequently the least-cost option for electricity development. As has been described in chapter 5, the electricity grid only covers a small proportion of the country, mainly around Vientiane. Although the size of the potential market for small-scale hydropower equipment is therefore large, even accounting for the small population of the country, the actual demand for hydropower schemes is severely restricted by financial limitations. The country is reliant upon aid from other countries and from charity organisations for the majority of the technological equipment it has acquired.

So far just over twenty micro-hydropower schemes have been built. There are definite plans for at least a further five schemes and substantially more than 50 sites are considered to be worth further study. There are immediate plans to develop at least four mini-hydropower schemes, however, in most areas villages are too dispersed for mini-hydropower developments to be economical. It has been suggested that most villages have a maximum demand for electricity of around 20kW. As the rural population is so dispersed, there is likely to be a large market for Family-hydropower equipment, however, again this is restricted by the financial limitations faced by people living within the subsistence economy. Micro-hydropower development has mainly been funded by foreign aid, and this is likely to remain the case for the foreseeable future. Larger hydropower schemes designed to supply electricity for export to Thailand are likely to

receive both government and private investment, but there is not likely to be such funding made available for mini-, or micro-hydropower projects.

7.3.2. Hydropower development

The development of micro-hydropower schemes in the Lao PDR has been erratic and piece-meal, mainly due to the number of agencies and suppliers of equipment involved. Many of the schemes are now in a state of disrepair, or are operating at low efficiency, and local engineers are not able to obtain the necessary spare parts, and are often inadequately trained to perform the required repair tasks.

The following recommendations are made with the intention of improving the prospects for sustainable development of small-scale hydropower schemes within the country.

- A micro-hydropower development plan should be created in conjunction with all the agencies presently competing for aid funding for such projects.

- The lack of infrastructure in the Lao PDR is a major problem affecting scheme sustainability. Funds should be requested from charitable NGOs and international aid organisations involved in micro-hydropower development, such as the UNDP, to provide repair and maintenance infrastructural support for existing schemes. This would best be achieved via regional workshops and outreach services provided by these workshops, in conjunction with the provincial department of the Ministry of Industry and Handicrafts. The cooperatives which own the schemes should be requested to pay for any repairs whereas the money from charitable NGOs and aid organisations should be used to pay for travel to the sites, and for maintaining the necessary infrastructure.

- Adequate training in repair and maintenance is essential for the Lao PDR, which is comparatively isolated, and cannot afford to rely upon distant experts. In-country training of local operators is always essential, and should be undertaken by implementing organisations by involving future operators in the installation of powerhouse equipment at the site, followed by on-the-job training once the equipment is operating.

- The provision of credit facilities to rural cooperatives is required in order to pay for maintenance and repair even to those schemes which have been fully funded via foreign aid. It is also essential to those people wanting to install house wiring.

- Family-hydropower units will continue to be privately bought, and it is recommended that installation advice and support should be given to purchasers by local government offices, as has been the case in parts of Vietnam.

- Rice milling should form the base load for most micro-hydropower schemes.

- It will be important to promote the local manufacture of smaller micro-hydropower equipment, as will be described in section 7.3.3.

As the geographic, demographic and socio-economic situation in the Lao PDR is similar to that found in Nepal, it is likely to be advantageous for the Lao PDR to learn from the Nepalese example. The deregulation of micro-hydropower schemes is considered to have been the most effective policy change within Nepal, having created a situation whereby it can be profitable for local investors to develop micro-hydropower schemes. By 1988, 600 private sector micro-hydropower schemes had been installed in Nepal [Cromwell, 1992]. The low failure rate of the schemes has been partly due to the decentralised management of the schemes and the fact that users have an investment in the project. Micro-hydropower in Nepal competes best with other energy sources when the site is at least two to three days walk from a town. Potential sites are initially assessed by a development consulting service which conducts a site survey and feasibility study, submitting a report to the Agriculture Development Bank of Nepal for financing if the site is found to be economically and technically feasible. The bank will provide 80% of the project's costs, paid directly to the implementing agency, as well as all of the expenses of the local entrepreneur. Repayment is then expected over a five to seven year period with an interest rate of approximately 11% [Sosthenes Buatsi, 1988]. The interested developer pays the consulting charge made for the site assessment, and a further charge is made if the site is suitable. The consultant then acts as an intermediary between the banks, purchaser and manufacturer. Figure 7.3 shows the responsibilities of the consultant, who is often the equipment manufacturer, and those of the site owner. If the following recommendations are pursued, then micro-hydropower could become equally successful in the Lao PDR:

- ownership of generating equipment and sale of electricity from micro-hydropower schemes by private individuals, or groups, should be permitted in law;

- the Department of Micro-hydropower of the Ministry of Industry and Handicrafts, with support from the UNDP, should approach both banks and credit suppliers within the country, so that they are made aware of potential investment into micro-

Tasks undertaken by the manufacturer	Responsibilities of the mill owner
Perform initial survey	Obtain the necessary licence to build and operate a mill
Design and fabricate turbine, penstock, and other required hardware	Purchase the land and right-of-way for the power canal and tailrace
Provide technical guidance and assistance in installing and commissioning of the plant	Arrange for water rights
	Locate sufficient cash to cover at least a portion of the total cost of the installation and apply for a loan for the balance
Train one of the local people designated as mill operator in how to operate and maintain the machinery	Organise local labour to undertake the necessary work
	Undertake the necessary excavation and collection of local materials (sand, stone and gravel)
	Transport all the hardware and materials to the site

[Source: Adapted from Inversin, 1986]

FIGURE 7.3: Division of responsibilities for the installation of a micro-hydropower scheme in Nepal

hydropower schemes;

- charitable NGOs which are considering funding micro-hydropower schemes in the country should be requested to support local entrepreneurial mill owners as well as local manufacturers, both by providing finance and technical support.

7.3.3. Local manufacture and technology transfer requirements

The Lao PDR has principally been dependent upon imported small-scale hydropower equipment. One of the main problems with this has been that virtually all of the projects have been packaged in such a way that little technology transfer has taken place. Due to this, and the fact that most schemes are implemented on a one-off basis, with equipment being supplied from many different sources, each requires different components when repair is needed, and the country is very much dependent upon outside assistance.

Few companies within the Lao PDR are capable of mastering and absorbing the technology required to manufacture micro-hydropower equipment. At present, only basic agricultural tools are made within the country. The development of technological capabilities by local manufacturers is hampered by the restricted market within the country, which restricts economies of scale, and by the competition from donated equipment. Some local manufacture of equipment has taken place, but as yet this has not firmly established itself, with only a few crossflow turbines having been fabricated within the country.

It is recommended that initially powerhouse equipment should continue to be imported for both micro- and mini-hydropower schemes, whilst manufacturing and design skills

are slowly absorbed. The necessary manufacturing know-how will best be absorbed if engineers from the Agricultural Tools Making Factory, for example, were to visit local manufacturers either in Chiang Mai, or Nepal. In conjunction with this, an engineer with experience of local manufacture should be engaged to work at the factory for a period of several months whilst production capabilities become established. Both of these would need to be funded by charitable organisations, or as part of an infrastructure building project which could possibly be funded by the UNDP.

Scheme design and implementation would best be obtained by engineers from the Department of Micro-hydropower, and the Department of Irrigation and Micro-hydropower, and from the Agricultural Tools Making Factory, all within Vientiane. For the near future it is likely that scheme design will continue to be undertaken by foreign consultants working for funding organisations. There are existing capabilities for civil work construction in many of the provinces.

As the market for micro-hydropower equipment is not likely to be lucrative enough to attract private foreign investment for local manufacture within the country, if manufacturing facilities are to be established it will be the responsibility of NGOs, the Lao government, or workshops themselves to instigate production and enable the absorption of the technology. It is considered that in the case of the Lao PDR, NGOs such as ITDG and SKAT will be relied upon to transfer the required technology. The Agricultural Tools Making Factory in Vientiane is the most suitable organisation to receive and develop the capabilities.

To build up the manufacturing capabilities within the Lao PDR it is advisable to concentrate initially upon producing crossflow turbines of capacities below 50kW, and to import ELCs, perhaps from Thailand, with the ballast load tanks being produced in the Lao PDR. Ultimately it may be possible to assemble ELCs locally, the design and parts of which may be obtained from abroad. As most villages are likely to have a maximum demand of 20kW, a set of standard crossflow units could be made for a variety of heads, and associated water flow rates. Present capabilities are adequate for the production of Family-hydropower units and perhaps Pelton turbines, if there is the will to do so. It is considered that the manufacture of other types of equipment and turbines above 50kW is not practical, or likely at the present time. The Lao PDR will not be in a position to produce mini-hydropower equipment as this would be too big a technological leap without a sufficiently skilled workforce, and too small a market within the country.

For ELC equipment to be assembled within the country, technical advice and training could be obtained via ITDG, for example, and funded via a charitable NGO, such as the Mennonite Central Committee, or as part of an infrastructure building project funded by the UNDP, working in conjunction with a Lao government agency. The micro-hydropower coordinating agencies within the country also need to be aware of the need for cheap ELC governing equipment.

There is also a demand for transfer of the technology required to produce Family-hydropower equipment within the Lao PDR. The Agricultural Tools Making Factory in Vientiane have adequate production capabilities, assuming that the permanent magnets are obtained from abroad. They have also expressed their interest in manufacturing the equipment. It is possible that they will attempt to copy the product, although it would be more satisfactory if training and technical advice were provided by the Vietnamese manufacturers of the equipment, for example.

As reconditioned synchronous generators are relatively cheap within the Lao PDR, and as neither induction generators nor electronic equipment are assembled within the country, the advantages of using IGCs and induction generators are minimal at the present time. If in the future the market for micro-hydropower units of capacity between 5kW and 30kW increases dramatically, and it is found that reconditioned synchronous generators are either too unreliable, or are becoming more expensive than imported induction generators, then this will be the time to invest in IGCs. At this point it is anticipated that both IGC units and the induction generators would still best be imported.

One possibility is to develop local manufacture in conjunction with a repair and maintenance facility to support existing schemes. Vientiane, Luang Prabang and Pakse (Champassak province) would each be good places for this to be established, as workshop facilities already exist in these towns/cities. Funding could be requested from the UNDP to establish both repair and maintenance at these workshops.

As in Vietnam, synchronous generators from disused diesel sets could be used where the speed of generator and turbine are suitable.

7.3.4. Additional recommendations to electricity utilities and the Lao government

As has been described in section 5.4.3, micro-hydropower developments in the Lao PDR have occurred in an uncoordinated way, and as such there has been little possibility for the transfer of technology to Lao organisations. A clearly defined policy with respect to

micro-hydropower development should be established so that intergovernmental organisations and NGOs can be part of a structured programme. This should include requests to the donor organisations to promote Lao-made equipment, and to purchase Lao-made equipment for development of schemes below 30kW in capacity. Above this capacity, or where locally-made equipment cannot be purchased due to the nature of the funding, emphasis should be placed upon standardisation of equipment so that dependency upon many suppliers does not continue.

Establishing a country-wide policy whereby private organisations, communities or individuals can own and sell electricity from micro-hydropower schemes is likely to encourage the development of new schemes.

In order to provide repair and maintenance support both to private and government initiated schemes, regional workshops need to be provided with the necessary finances.

7.3.5. Recommendations to funding agencies and NGOs

It is suggested that if organisations are sincere in their wish to promote the sustained use of micro-hydropower within the Lao PDR, then they should help fund the establishment of local manufacturing capabilities, rather than funding one-off schemes which ultimately undermine the local manufacturing industry, and lead to dependency. Rather than funding packaged developments whereby foreign experts design, build and commission micro-hydropower schemes, with the only transfer of technology being the training of local operators, it is recommended that NGOs and other funding organisations should promote the unpackaging of the technology, and fund training in manufacture and scheme implementation. NGOs are in a good position to promote the establishment of local manufacturing capabilities for micro-hydropower equipment, as has been achieved successfully in Nepal.

The funding of regional repair and maintenance capabilities at existing workshops will be of benefit both to existing and future schemes.

7.4. STRATEGIES FOR THE FUTURE: THAILAND

7.4.1. Markets and demand

It is generally considered that the need for micro-hydropower developments in Thailand is diminishing, as the local and national grids extend to cover the vast majority of the

households in the country. This view, however, does not take into account the remote highland communities which so far have not received an electricity supply, where micro-hydropower or mini-hydropower will often prove to be the least-cost option. Approximately 1,200 villages, with an average of 100 households per village, are likely to remain without an electricity supply when the present PEA rural electrification programme is completed. There is, however, a political commitment to electrify virtually all of the country's villages, and there is a willingness by most villagers to pay for small amounts of power. Many villagers without a supply are presently paying for small amounts of electricity from batteries at a cost of up to US$1.90/kWh [Meridian Corporation], and others are paying up to US$4.20 per month for poor quality kerosene lighting. Also there is an acute lack of fuelwood particularly in the North-East, where forest resources are expected to disappear within the next ten years.

The new 'Masterplan' for micro-hydropower will ensure the continuing development of micro-hydropower schemes for several years to come. The rate of development is likely to remain similar to the past, at approximately six schemes per year.

Several mini-hydropower schemes are to be built, however, the market is restricted due to the extensive reach of the national grid, although in some places mini-hydropower schemes are being used to support the extremities of the grid.

Family-hydropower units are only likely to be of use in the border regions of the country, in those villages in hilly areas which are unlikely to receive electrification in the near future.

A major small dam building programme throughout the country has created many potential sites for low-head micro-hydropower schemes, particularly with a capacity of around 20kW. Although it is technically feasible to develop micro-hydropower schemes at many of these sites, it is unlikely to be economically advantageous as virtually all are situated near to villages which already have a grid connection.

7.4.2. Hydropower development

There is a relatively well coordinated infrastructure for micro-hydropower development in Thailand, with good provisions being made for maintenance and repair. Micro-hydropower schemes have successfully been operated and managed by the local communities with continued support from the NEA/DEA. It is important that training and support for operation and maintenance continue to be provided with repair, and

further maintenance services being supplied from Chiang Mai and Bangkok.

It is recommended that mini-hydropower schemes continue to be owned by the utilities, and operated by them. It will be advantageous to standardise equipment imported for larger schemes. The PEA have expressed their satisfaction with using turgo turbines, as they can still be operated when the water levels drop in the dry season and suffer from fewer problems than Francis turbines, for example, with the ingress of sand and sediment [Chulapongs Chullakesa, 1991 (b)].

The micro-hydropower schemes established in Thailand have been expensive due to the often excessive civil works. Costs can be reduced by using more appropriate civil work designs and materials, as has been described in chapter 2.

Micro-hydropower and in some situations Family-hydropower units could be used to provide a basic supply to those villages which are not likely to receive electricity via government programmes. Promotion of their sale should be undertaken via the NEA/DEA which has seven regional energy centres to disseminate, demonstrate and promote the use of suitable new and renewable energy technologies to rural villagers. Family-hydropower equipment could either be manufactured in Thailand, or imported from Vietnam. Once it has been determined which villages will not receive a PEA, or NEA/DEA supply, provisions should be made for credit services and subsidies to be supplied and promoted, in order that some village cooperatives can obtain funds to develop a scheme where this is economically and technically feasible. These credit packages could be provided via the Bank of Agriculture and Agriculture Cooperatives, which has closest contacts with rural communities. Such credit services will be of wider benefit as nearly 15% of households which have already participated in the construction of micro-hydropower systems have been unable to afford the cost of a connection to the network [Helling, 1986].

The use of ELCs has provided a relatively cheap and reliable form of governing within Thailand, and their continued use is considered as essential in order to reduce the cost of micro-hydropower schemes.

7.4.3. Local manufacture and technology transfer requirements

All of the equipment for micro-hydropower schemes with capacities below 100kW can be produced within Thailand. For many years the Mining and Industrial Machine Workshop in Chiang Mai have been making crossflow turbines for the NEA/DEA's micro-

hydropower schemes and their equipment has proved to be reliable and relatively cheap. Chiang Mai has been a suitable location for a micro-hydropower workshop, as it is closer to sites which have been predominantly in the North of the country.

Many other companies could produce crossflow and Pelton turbines, and pumps already being produced in the country could be used as turbines. However, whereas using pumps-as-turbines in conjunction with induction generators and IGCs would probably provide some savings over existing costs for powerhouse equipment below 25kW, in comparison to civil work costs and overall scheme development costs in Thailand, these savings would be minimal. Also, the demand for micro-hydropower equipment of medium-head is being fully met by the supply from the workshop in Chiang Mai, and thus there is no real potential for other manufacturers.

Virtually all of the equipment for mini-hydropower and larger schemes is presently imported, and it appears that this is unlikely to change in the near future. The skills and machinery needed for the manufacture of mini-hydropower equipment are different to those required for the production of micro-hydropower equipment. Although several companies have the machinery to produce mini-hydropower equipment, no company within Thailand presently has the necessary design skills, or experience to produce such equipment. It is presently not economically attractive to produce mini-hydropower equipment within Thailand due to the small number of schemes being implemented in the country each year.

The approach recommended is to continue to manufacture crossflow equipment below 100kW. Although the production of cheap Family-hydropower units could create a substantial market in Thailand, it is suggested that initially equipment be imported from Vietnam, until the extent of the market becomes more clearly understood. The existing workshop in Chiang Mai, or the ATA in Bangkok, would be suitable organisations to produce the equipment if the market were large enough. Transfer of manufacturing know-how should take place via visits by ATA and NEA/DEA engineers to the Vietnamese producers, with funding coming from the NEA/DEA, or a charitable NGO in the case of the ATA.

ELCs which are being successfully produced by the NEA/DEA will be of interest to the implementers of both Lao and Vietnamese micro-hydropower schemes. Whereas there are good prospects for such equipment to be produced within Vietnam in the near future, this is not the case in the Lao PDR, and it is recommended that the NEA/DEA contact the Ministry of Industry and Handicrafts in Vientiane. Export assistance is available in

Thailand from government organisations such as the Department of Export Promotion, of the Ministry of Commerce.

7.4.4. Additional recommendations to electricity utilities and the Thai government

It is vitally important that the PEA provides reliable information with respect to which villages are likely, and which are unlikely, to receive an electricity supply from the existing PEA programme, so that informed decisions can be made by other implementing organisations and village communities. For those villages which are unlikely to receive a government supply, there is a requirement for the establishment of a loan scheme to provide funds for long term financing of schemes so that they are able to buy and establish a scheme.

The policy of enabling village cooperatives to own and produce electricity from micro-hydropower plant, with repair and maintenance support being provided by the regional NEA/DEA micro-hydropower team, is likely to continue to be effective and should be extended to cover all schemes, whether developed by the NEA/DEA, or other organisations.

There are many opportunities for reducing costs in the micro-hydropower range of schemes in Thailand. For example, by using wood-concrete weirs as opposed to concrete mass weirs which are substantially more expensive, as has been highlighted in section 2.1.

Whilst powerhouse equipment needs to be continued to be imported for the mini-hydropower programme, it is important for counterpart staff to be involved with the design, construction supervision, installation of equipment and commissioning, in order to learn and absorb the technology.

7.5. STRATEGIES FOR THE FUTURE: THE SOUTH-EAST ASIA REGION

7.5.1. Regional cooperation

The countries of South-East Asia are experiencing many political and economic changes, which are creating new opportunities for increased cooperation and trade. Recently there have been significant improvements in relations between Thailand and Vietnam, and progressively improving relations over the last few years between Thailand and the Lao PDR. Both Vietnam and the Lao PDR are considering joining the ASEAN, of which

Thailand is a founding member.

Regional cooperation is hindered by an insufficient institutional framework at the international level, and also by incompatible standards for powerhouse equipment. Intergovernmental and international organisations can create an infrastructure to enable joint development.

There are plans for the development of an electrical grid connection between all of the ASEAN countries. Cooperation in the development of medium- and large-scale hydropower schemes has taken place between Thailand and the Lao PDR, with sale of electricity between the two countries, and there are plans for several other projects to be implemented by the year 2000. Thailand and Myanmar are considering the possibility of cooperation in the construction and sale of electricity from several hydropower schemes ranging from 12.5MW to 4540MW [WPDC, 1992 (b)]. Thailand is also considering joint cooperation with Cambodia [WPDC, 1992 (b)]. There have been no joint development plans between Thailand and Vietnam, and this is likely to remain the case due to the shortage of both electrical capacity preventing sale from Vietnam, and the lack of foreign capital preventing electricity purchase by Vietnam.

The international organisation, the Mekong Committee, has been promoting the development of hydropower throughout the Mekong Basin, principally with respect to large-scale schemes, though they have also instigated a joint project involving the three countries under study in the construction of three micro-hydro schemes: Houey Salot (200kW) in the Lao PDR, Lam Chang Han (126kW) in Thailand, and Ea H'Leo (200kW) in Vietnam. The main aims of the projects are to promote the standardisation and the local manufacture of micro-hydropower equipment within the region. Being partly funded by international donors, the first turbine will be obtained from China, and the subsequent equipment will be based upon this design and produced in Vietnam.

Vietnam, Cambodia and France have been jointly involved in the development of the Ochum 510kW mini-hydropower scheme in Cambodia, and there are plans for similar cooperation in the construction of a larger 1MW scheme [WPDC, 1992 (d)]. Penstock fabrication and civil works construction were the main responsibility of the Vietnamese, whereas technical assistance and virtually all of the powerhouse equipment was obtained from France.

The Electrical Equipment Designing Enterprise in Vietnam have installed several of their micro-hydropower turbines in the Lao PDR and Mongolia [Nguyen Khac Diem, 1992],

and some Family-hydropower units made in Vietnam have been donated to the Lao PDR.

Other countries within the region are involved in the production of hydropower equipment and scheme development. China produces more hydropower equipment than any other country in the world; Myanmar has produced crossflow turbines with capacities up to 300kW, whilst importing other types of turbines [Mehm Thet San, 1991]; no powerhouse equipment has yet been made in Cambodia; there is a large manufacturing base in Indonesia; and whereas the Philippines has a great potential for small-scale hydropower development, very little equipment has been locally manufactured. The ASEAN countries present a large market for hydropower equipment, particularly the Philippines and Indonesia.

The World Bank is prepared to fund small-scale renewable energy and energy efficiency projects in Thailand and other ASEAN countries, via their FINESSE (Financing Energy Services for Small-Scale Energy-users) initiative. Although the funding will not be made available for hydropower developments within Thailand, if the scheme is successful then there is a possibility of it expanding by way of increasing the number of countries involved, and also the technologies eligible for funding within those countries. By grouping small projects in order to obtain funding at lower rates of interest than would usually be available for such projects, FINESSE aims to reduce the cost of renewable energy and energy saving equipment. Another potential source of funding for small-scale hydropower projects within the three countries under study is the Global Environmental Fund (GEF). This fund has a total of US$3 billion to provide grants and loans to developing countries to assist in implementing programmes which protect the global environment.

The total market for mini- and micro-hydropower equipment in the region is estimated in figure 7.4. The lower estimate of 15,000kW of capacity to be installed per year results in a market for powerhouse equipment of over US$9 million per year in the three countries under study, taking the cost of hydraulic and electrical equipment to be US$600 per installed kilowatt†, and US$4.5 million if Vietnamese equipment were used‡. If, for example, only a quarter of these schemes were built, this would be sufficient to support several small manufacturing companies.

---

† This figure of US$600 (£400) per installed kilowatt is taken from Wallace [Wallace, 1990] as a typical cost for intermediate technology powerhouse equipment.

‡ A conservative estimate of US$300 per installed kilowatt is used for Vietnamese equipment.

	Estimated average number of schemes to be developed per year (1995 - 2000) including renovations	Estimated average installed capacity per year (MW)
Vietnam		
Family-hydropower	>200	>0.05
Micro-hydropower	>10	>0.5
Mini-hydropower	>10	>10
Lao PDR		
Micro-hydropower	2	0.1
Mini-hydropower	<1	<0.5
Thailand		
Micro-hydropower	4	0.4
Mini-hydropower	2	3
TOTAL	>226	>14.5MW

FIGURE 7.4: Anticipated market for mini- and micro-hydropower equipment in the three countries under study

The following cooperation between the three countries under study is recommended:

- transfer of the manufacturing capabilities for the production of Family-hydropower equipment, from the RERC in Vietnam to the Agricultural Tools Making Factory in Vientiane, as described in section 7.3.3;

- Family-hydropower equipment to be exported from Vietnam to Thailand, as described in section 7.4.3;

- ELCs made in Thailand to be exported to the Lao PDR.

It is considered that the sale of mini-hydropower equipment from Vietnam to Thailand is not likely, as the Thai mini-hydropower market demands equipment of high efficiency and reliability. Vietnamese equipment, however, is considered to be less efficient and less reliable than that from European manufacturers, for example. There are, however, possibilities for the sale of micro-hydropower equipment from Vietnam to both the Lao PDR and Thailand, for sites where the use of impulse turbines is not appropriate.

7.5.2. Recommendations to funding agencies

As has been shown in chapter 3, aid in the form of donations of hydropower equipment is not always beneficial to the recipient country, as it can undermine attempts by local companies to manufacture the equipment and become more self-reliant. Also, dependency upon foreign suppliers for spare parts or technical assistance is often a great burden upon the recipient's resources. International donor and funding organisations, including NGOs, can promote local manufacture by both purchasing locally made equipment and providing financial and technical support to that industry.

People in the hilly areas are not often able to afford the cost of installation, or connect to a scheme, without outside financial assistance in the form of loans or subsidies. Loans to rural people are often considered to be high risk, as the recipients have few possessions to act as collateral, and therefore interest is often set at a high rate. It is seldom realised by lenders that the energy system itself can be used as collateral to secure the loan. This happens in India for example, where loans can be obtained for up to 75% of the cost of investment into mini- and micro-hydropower schemes. With an initial three year moratorium on repayment, total repayment is then expected within a period of ten years [IREDA, 1992]. A similar scheme would promote micro-hydropower development within South-East Asia, if initiated in conjunction with legally established village cooperative groups or with individual mill owners, as has been the case in Nepal.

Many countries are interested in obtaining the capabilities to produce Family-hydropower equipment. It is suggested that an organisation such as GTZ-GATE, or ESCAP, pay for the production of detailed designs and manufacturing instructions, so that they are able to distribute the information to interested manufacturing organisations. Funding is presently being sought for such an initiative following recommendations from the author.

7.6. OTHER RECOMMENDATIONS

7.6.1. Maximum capacity for manufacture of turbines in small workshops

Crossflow turbines are the simplest turbine to produce, followed by Pelton and Turgo turbines, whereas the reaction turbines of Kaplan and Francis are considerably more difficult. The type of equipment which can be produced at a workshop is dependent upon the skills and machinery available, as well as design expertise. This varies from country to country and from manufacturer to manufacturer.

It is evident from the experience of the three countries under investigation that crossflow turbines up to between 70kW and 100kW can be produced within a small workshop, if support and advice is available at the outset from both designers and people with experience of producing the equipment. It has also been found that crossflow turbines may still be produced from published designs up to approximately 40kW, however, the quality and reliability of these turbines is likely to be lower than if adequate support and training were available. Pelton turbines and Family-hydropower units can also be produced by such small workshops, particularly where casting facilities are available, and if support and training are available.

Reaction turbines with capacities up to 1.5MW have been produced effectively by larger workshops in the countries under study, although without the efficiency of the best designs. The manufacturing tolerance is much more critical for this type of turbine. The available skills and machinery need to be more advanced, and casting facilities are essential.

7.6.2. Factors contributing to the successful development of local manufacturing capabilities

Local manufacture of powerhouse equipment provides both cost reductions over imported equipment, and support for repair and maintenance. Following is a list of findings from the study which have an effect upon the establishment of small-scale hydropower local manufacturing capabilities.

- In Vietnam and Thailand, small companies have been the most effective at producing equipment which is adequate in terms of quality, whereas all of the larger companies have ceased to manufacture turbine equipment.

- Local manufacturing capabilities develop best where there is knowledge of a strong market for such equipment. Development plans are thus beneficial, as is a policy by electricity utilities to buy locally produced equipment.

- The location of a manufacturer is important to its success, with requirements for adequate transport facilities, and a good supply of raw materials and skilled labour.

- Manufacture is more easily established where there is already a strong manufacturing base for other similar products.

- There is wide scope for reducing the cost of hydropower equipment. The cost of hydropower equipment can be reduced, particularly for units with low capacity, where efficiency is not so important and the equipment experiences lower mechanical forces. Similar reduction is seldom possible in the mini-hydropower.

- The type of equipment manufactured needs to be suited to the skills, machinery, resources and capabilities of a particular company.

- Support from other agencies, for example NGOs, or electricity utilities is essential during the initial process of establishing manufacturing capabilities.

- Non-optimum siting of reaction turbines can lead to rapid cavitation and damage, and thus possibly a poor reputation for the manufacturer.

- Choosing the best source of a technology and effective unpackaging of that technology by small companies is seldom possible. National engineering and consultancy services can be of aid with this process.

- It is essential that proper assessment of in-country skills, capabilities and resources be made, such that training can be geared to the requirements, and local skills and materials can be used effectively.

CHAPTER EIGHT: CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

8.1. CONCLUSIONS

The terrain found throughout much of Northern and Central Vietnam, Northern Thailand and virtually all of the Lao PDR is suitable for the development of mini- and micro-hydropower schemes. These regions generally coincide with those areas which have little rural electrification coverage, and in many cases mini- and micro-hydropower development will be the least-cost option for an electricity supply.

It is generally considered that the need for micro-hydropower developments in Thailand is diminishing, as the local and national grid extend to cover the vast majority of the households in the country. However, there are approximately 1,200 villages which are unlikely to receive an electricity supply under existing rural electrification programmes. The majority of these villages lie in remote highlands and islands where the least-cost option for a supply will often prove to be small-scale hydropower schemes. In the Lao PDR less than 2% of the rural population have access to electricity. The terrain of the country, the high levels of rainfall and the dispersed population again make small-scale hydropower developments a suitable choice for rural electrification. This is also the case throughout much of Vietnam, where less than 14% of the rural population have an electricity supply.

Over 50 micro-hydropower and 15 mini-hydropower schemes have so far been developed in Thailand. The schemes are well constructed and supported, and generally provide a reliable supply, however, the micro-hydropower schemes in particular have been characterised by high civil work costs. So far, more than twenty micro-hydropower sites have been built in the Lao PDR, nearly all receiving outside assistance, with the country being reliant upon aid for the majority of its rural development and technology. Over 400 small-scale hydropower schemes have been established in Vietnam, however, half of the sites built in the country are now not in operation mainly due to cavitation of the reaction runners used, as a result of the poor siting of turbines. Such a large number of schemes needing repair demand substantial investment for renovation, but this provides an opportunity to equipment manufacturers and scheme developers alike. With the basic structures of these schemes being ostensibly in place, investment to enable operation is likely to be low.

In Vietnam, the way forward most likely to be effective in the short term will be to repair disused sites, and improve the provisions for maintenance and repair facilities. It is suggested that regional, or in some cases provincial, repair and maintenance support be established, with a minimum of one such team in each of the regions of the North, Centre and South. Adequate training in repair and maintenance is essential for all of the countries, however, it is hampered and made more expensive due to the inaccessibility of the terrain and lack of road infrastructure, particularly in Vietnam and the Lao PDR where adequate support does not presently exist. Such an infrastructure exists in Thailand, where this has been effectively carried out by a small team of engineers working under the NEA/DEA, and it is recommended that this be extended to cover both utility owned and private sites. The creation of a similar repair infrastructure for both utility and private sites is an important step which must taken in both Vietnam and the Lao PDR if small-scale hydropower developments are to become sustainable.

Manufacturing capabilities	Vietnam	Lao PDR	Thailand
Turbines	200W - 1.5MW Francis, Kaplan, crossflow, Pelton and propeller	5 - 40kW Crossflow	5 - 70kW Crossflow Pelton - not presently made
Governors	Hydraulic	None	ELCs
Others	Generators, transformers and penstock	Penstock	Generators, transformers and penstock

FIGURE 8.1: Manufacturing capabilities of the three countries under study

All of the equipment for micro-hydropower schemes with capacities below 100kW can be produced within Thailand, with the crossflow micro-hydropower units presently being built in Thailand having proved to be both reliable and relatively cheap. Virtually all of the equipment for mini-hydropower and larger schemes is presently imported, and it appears that this is unlikely to change in the near future. Very little local manufacture of powerhouse equipment has taken place in the Lao PDR. To build up the manufacturing capabilities within the Lao PDR it is advisable to do so in conjunction with a repair and maintenance workshops, and to concentrate initially upon producing crossflow turbines of capacities below 50kW. All equipment required for a small-scale hydropower project is also being produced within Vietnam. Figure 8.1 summarises the manufacturing capabilities of each of the three countries.

In Thailand, micro-hydropower turbine manufacturing capabilities have been acquired via in-country design and visits to developments in China. In Vietnam, little formal technology transfer has taken place, principally due to the scarcity of foreign capital, and the Vietnamese have therefore copied most of their designs for equipment. In the Lao PDR, where virtually all of the small-scale hydropower equipment has been donated by aid agencies, little has been done to transfer the technology to the country. Technology transfer can be considered to be successful when absorption and diffusion of the technology by the recipient company and recipient country respectively has taken place such that the transferred project is fully operating without outside assistance.

Aid in the form of donations of hydropower equipment are not always beneficial, as they can undermine attempts by local companies to manufacturing the equipment and become more self-reliant. Dependency upon foreign suppliers for spare parts, or technical assistance, is often a great burden upon the recipient's resources. It is recommended that for the Lao PDR in particular, standardisation of equipment should be attempted so that dependency upon many suppliers does not continue.

Local manufacturing capabilities develop best where there is knowledge of a strong market for such equipment, as can be established by a 'Masterplan'. Such plans should be developed in the Lao PDR for micro-hydropower schemes, and in Vietnam for both mini-hydropower and micro-hydropower schemes.

In Vietnam and Thailand, small companies have been the most effective at producing equipment which is adequate in terms of quality, whereas all of the larger companies have ceased to manufacture turbine equipment. It is evident from the experience of the three countries under investigation that crossflow turbines up to between 70kW and 100kW can be produced within a small workshop, as can Pelton turbines and Family-hydropower units. In the micro-hydropower range there are possibilities of using cheaper construction methods than those used for larger equipment, as the forces upon the equipment are lower and equipment efficiency is often not so important. It is essential that proper assessment of the in-country skills, capabilities and resources be undertaken, such that training can be geared to the requirements and local skills, and materials can be used effectively. In each successful case, either government, or electricity utility support was provided during the initial stages of establishment. National engineering and consultancy services are needed to help small companies to choose the best source of a technology and to enable the effective unpackaging of that technology.

Flow control equipment is difficult to produce, requiring precision manufacture, whereas Electronic Load Controllers can be used for micro-hydropower sites where there is not a need for water conservation. The use of ELCs in Thailand has provided a relatively cheap and reliable form of governing, avoiding the need for an operator being required at all times. ELCs are needed in both the Lao PDR and Vietnam, as in both countries, at present, the majority of schemes with capacities below 100kW are manually operated, in many cases placing too high a burden upon the recipient community. It will be best to import ELCs into the Lao PDR, with the ballast load tanks being produced locally, whereas it is now practical to transfer the technology into Vietnam.

Synchronous generators are being manufactured in both Thailand and Vietnam, however, in the latter's case the availability of cheaper disused diesel generators has resulted in them being the main source of generator for small-scale hydropower schemes.

Family-hydropower units have become popular due to their low cost, ease of installation and light weight. So far around 3,000 units have been installed in Vietnam, and many others in the North of the Lao PDR. Vietnamese-made units are not as popular as those from China as they are more expensive, however, they have been proven to be more efficient and reliable. Within several provinces of Vietnam the extensive use of Family-hydropower units warrants the establishment of small advice-giving and installation groups, which could be jointly funded by the provincial government and charitable NGOs. There is a demand for transfer of the technology required to manufacture Family-hydropower equipment within the Lao PDR. Many other countries are also interested in obtaining the capabilities to produce Family-hydropower equipment, and it has been recommended that designs and production details be documented to enable the dissemination of the technology.

Little formal technology transfer has taken place within the region, or to the countries within the region. The following cooperation between the three countries under study is recommended:

- technology transfer of the manufacturing capabilities for the production of Family-hydropower equipment, from Vietnam to the Lao PDR;
- Family-hydropower equipment be exported from Vietnam to Thailand;
- ELCs be exported from Thailand to the Lao PDR.

	Vietnam	Lao PDR	Thailand
Main problems:	Cavitation of turbines	No build-up of experience Lack of infrastructure	Excessive cost of civil works for micro-hydropower schemes
Recommendation:	Better siting of turbines and use of better de-silting structures	Unpackaging of technology and establish manufacturing capabilities for micro-hydropower	Use more appropriate construction methods and local materials
Main technology transfer needs:	ELC manufacture and use Designs for improved efficiency of turbines	ELC use Crossflow manufacture General know-how concerning scheme development	Possibly Family-hydropower equipment Further capabilities to enable design and construction of mini-hydropower schemes
Need for ELCs?	Yes - produce locally	Yes - import	Already being made and used
Need for IGCs?	Yes - produce locally	Not at present	Not at present
Local manufacture investment from:	Foreign companies and existing Vietnamese manufacturers	Charitable NGOs and the UNDP	Continue as at present
Repair and maintenance:	Establish regional support infrastructure	Workshops in provinces	Already good facilities and infrastructure in existance Extend to cover private schemes
Funded by:	Tax on electricity	Charitable NGOs/UNDP, and by scheme owners for repair	NEA/DEA, as is already the case
Micro-hydropower developments to be funded by:	Government investment via international loans, and from foreign investment, eg BOOT	Charitable NGOs and the UNDP	Government, and from village cooperatives with loans obtained from credit suppliers
Family-hydropower:	Advice and support organisations established in provinces where Family-hydropower is popular	Advice and support organisations established in the North where they are more popular	Import initially Could be produced with transfer of the technology from Vietnam
Recommended changes to the law:	Utilities to be required to purchase electricity at the same price as it presently costs them to produce Private generation permitted	Permit the ownership of equipment and sale of electricity to others	The PEA should be forced to make explicit its plans for rural electrification, or not, of individual villages
Need for a 'Masterplan'?	Yes - one each for mini- and micro-hydropower	Yes - one for micro-hydropower, involving all agencies	'Masterplans' already used

FIGURE 8.2: Recommendations to the three countries under study

Figure 8.2 summarises the recommendations made to the three countries. In each case, the transfer of these technologies should be made to existing companies within the region.

Companies which are presently producing hydropower equipment are generally reluctant to transfer technology to another organisation, as this is likely to result in the loss of a market for their own products and the creation of a new competitor. However, in order to enter a market a company will often offer to transfer the technology needed to manufacture some of the components within that country, and whereas this is often welcomed by the recipient organisation, it often leads to dependency. Several NGOs, however, are willing to provide training to organisations in developing countries which are wishing to produce their own micro-hydropower equipment. Whereas the technology they are able to provide is often not the most efficient, or reliable, it is suited to the needs of developing countries in many cases.

The situation in Vietnam is such that there is a substantial market for both mini-hydropower and micro-hydropower equipment within the country. With the recent lifting of the long held economic embargo of Vietnam by the United States of America, financial resources will soon become available to enable the country to expand upon its infrastructure, which will include rural electrification networks. The mini-hydropower market in particular is attracting interest from foreign equipment manufacturers, and it is considered that a joint venture involving the injection of funds and the transfer of technology enabling the improvement of turbine efficiency and reliability will be perceived to be profitable by both the supplier and the recipient of the transfer. Joint venture agreements with Vietnamese manufacturers of equipment, and investment into mini-hydropower scheme development, on a BOOT or similar basis are likely to be more forthcoming if the foreign investment law is stable, and if electricity utilities are required to buy electricity at the price at which it costs them to produce it.

	Vietnam	**Lao PDR**	**Thailand**
Potential sites	Many potential mini- and micro-hydropower sites	Many potential mini- and micro-hydropower sites	Many potential micro- and some mini-hydropower sites
Manufacturing capabilities	For mini- and micro-hydropower equipment	Effectively no manufacturing capabilities	For micro-hydropower equipment
Likely demand for powerhouse equipment	Likely to be a large demand	Little demand	Steady demand
Design and construction experience	Considerable design and construction experience	Little construction or design experience	Considerable construction experience, though little design experience other than for micro-hydropower

FIGURE 8.3: Summary of the situation within each of the countries

It has been shown that there are substantial markets for micro-hydropower powerhouse equipment within Vietnam, the Lao PDR and Thailand. There is also a large demand for mini-hydropower equipment in Vietnam and to a lesser extent in Thailand. Figure 8.3 summarises the situation presently found within the three countries. Small-scale hydropower equipment is being successfully manufactured within the region, however, it has been shown that there is need for improvements to be made, and a need for the transfer of technology both to and within the region.

8.2. RECOMMENDATIONS FOR FURTHER RESEARCH

As a complement to the research and findings presented here, the author considers the following research to be necessary in order to enable the development of small-scale hydropower schemes to take place in a sustainable manner within the region.

1) In Vietnam research is needed in order to assess each of the mini- and micro-hydropower sites presently in a state of disrepair. This should determine the nature and extent of the repairs required, and the local usage and demand for electricity, so that an order of priority for scheme rehabilitation can be specified. This will enable both implementing organisations and Vietnamese manufacturers to plan effectively.

2) Also in Vietnam a country-wide assessment of potential hydropower sites and the local demand for electricity needs to be undertaken. Such studies have been performed for some regions, and so these need to be brought together and studies undertaken in the remaining regions. In conjunction with the electricity companies' assessments of grid extension costs for the regions, and taking other supply possibilities into account, a least-cost electricity supply option can be determined for each town, and later for each village. This is obviously an enormous task, for which funding is likely to be required from international sources.

3) In the Lao PDR a similar assessment needs to be made to that prescribed for Vietnam in recommendation two. Whereas a country-wide assessment would be ideal, with the present financial constraints which the country faces it is recommended that focus is place upon the Boloven Plateau and around the country's main district and provincial towns.

4) In Thailand an individual assessment needs to be made of those villages remaining without electricity. This, again, should be designed to determine the likely electricity demand and the least-cost supply option for each village, and thus the role which small-scale hydropower can take.

5) In Vietnam and the Lao PDR, follow-up research will then be required to determine the effect which small-scale hydropower schemes are having upon the communities.

6) In each country continuous assessment of scheme and powerhouse equipment reliability is needed.

7) A thorough study of the reliability of both Vietnamese- and Chinese-made Family-hydropower equipment is needed. It has been found that organisations in several other countries are interested in both using and manufacturing such equipment.

8.3. POSTSCRIPT

Sections of this thesis are being sent to relevant organisations within Vietnam, Thailand and the Lao PDR. It is hoped that this study is useful to these organisations, and that the implementation of the recommendations made herein will help to bring benefit to rural people throughout the region.

BIBLIOGRAPHY

Adachi, 1992

Adachi, Hayao, "Report of microhydropower survey mission to Vietnam", Internal memorandum, Mekong Committee, Bangkok, August 1992.

ADB, 1991

Asian Development Bank, *Key indicators of developing Asian and Pacific countries - Volume XXII,* Economics and Development Resource Centre, Asian Development Bank, Manila, 1991.

Arter, 1992

Arter, A., "Do cross flow turbines have a future?", *Proceedings of the Fifth International Conference on Small hydro,* pp. 139-149, International Water Power and Dam Construction, Sutton, 1992.

Asian Energy News, 1991

Asian Energy News, "Southern Vietnam struggles with power shortages", *Asian Energy News,* vol. October 1991, pp. 5, Energy Technology Division, Asian Institute of Technology, Bangkok.

ATA, 1987

Appropriate Technology Association, "Progress report - micro hydropower project Jan 86 - July 87", Unpublished report, Appropriate Technology Association, Bangkok, 1987.

Balfour Beatty, 1990

Balfour Beatty, "Appraisal study of proposed rehabilitation of mini/micro hydro stations", Unpublished report for the Provincial Electricity Authority, Bangkok, October 1990.

Barrow, 1989

Barrow, A., "Acquiring technological capabilities: the CNC machine tool industry in industrialising countries, with special reference to South Korea", PhD thesis, University of Edinburgh, 1989.

Bartholomew

Bartholomew, *World travel map - Asia South-East,* Map scale 1 : 5,800,000, Merator Projection, Edinburgh, undated.

Blakeney, 1989

Blakeney, M., *Legal aspects of the transfer of technology to developing countries,* ESC Publishing Ltd., Oxford, 1989.

Brown

Brown, A., "Field notes - Thailand visit", Internal report, Intermediate Technology Development Group, Rugby, undated.

Chapallaz, 1992

Chapallaz, J., "Le transfert de technologie en microcentrales hydroélectriques - L'exemple du Népal", *Actes du colloque Avenir de l'hydroélectricité au Cambodge, au Laos et au Viêt Nam,* pp. 387-401, Institut de l'Énergie des Pays ayant en commun l'usage du Français, Québec, 1992.

Chulapongs Chullakesa, 1991 (a)

Chulapongs Chullakesa, "PEA's experience on rural electrification", Paper presented at Asia Energy '91: The First Asia International Exhibition and Conference on New and Renewable Energy Information on Policy, Planning, Technology and Equipment, Bangkok, 17-20 October, 1991.

Chulapongs Chullakesa, 1991 (b)

Chulapongs Chullakesa, "Technology applicable to Thailand's small hydro development", Paper presented at the Hidroenergia 1991 Conference, Nice, June 12-15, 1991.

Chulapongs Chullakesa, 1991 (c)
Chulapongs Chullakesa, "Technology applicable to Thailand's small hydro development", *SHP News,* vol. 3/91, pp. 7-15, Hangzhou Regional Centre for Small Hydro Power, China, 1991.

Chulapongs Chullakesa, 1992
Chulapongs Chullakesa, "Rural electrification in Thailand", in *Rural Electrification Guidebook for Asia and the Pacific,* ed. G. Saunier, pp. 439-454, Asian Institute of Technology, Bangkok, 1992.

Cromwell, 1991
Cromwell, G. and Pandey, B., "Feasibility study of micro-hydro projects in Bac Thai Province, Vietnam", Unpublished report for Co-operation Internationale pour le Développement et la Solidarité (CIDSE), Hanoi, 1991.

Cromwell, 1992
Cromwell, G., "What makes technology transfer? Small-scale hydropower in Nepal's public and private sectors", *World Development,* vol. 20, no.7, pp. 979-989, Pergamon Press, 1992.

Customs Department, 1989
Customs Department, *Customs tariffs of Thailand,* Customs Department, Bangkok, 1989.

Dam Xuan Hiep, 1991
Dam Xuan Hiep, "Quelques problems rencontres par les PCH dans les pays en developpement: l'example du Vietnam", Paper presented at the Hidroenergia 1991 Conference, Nice, June 12-15, 1991.

Dansie, 1994
Dansie, J., "Laos hydro to power Thai economy", *International Water Power and Dam Construction,* vol. March 1994, pp. 18-20, Reed Enterprise, Sutton, 1994.

Denton, 1979
Denton, F., *Lighting up the countryside: the story of electric cooperatives in the Philippines,* Development Academy of the Philippines, Manila, 1979.

Djeflat, 1988
Djeflat, Abdelkader, "The management of technology transfer: Views and experiences of developing countries", *International Journal of Technology Management,* vol. 3, no. 1/2, pp. 149-165, 1988.

Duder
Duder , J., et al., "Small scale hydro experience in New Zealand and East Malaysia", Paper produced by Tonkin and Taylor Ltd., Auckland, undated.

Economist, 1992
The Economist, "A dam shame", *The Economist,* vol. 11th April 1992, pp. 64, 1992.

ECIU, 1993
Economist Central Intelligence Unit, *Indochina: Vietnam, Laos and Cambodia - Country profile 1992 -1993,* London, 1993.

EGAT, 1989
Electricity Generating Authority of Thailand, *Introduction to EGAT's hydro power development,* Bangkok, 1989.

EGAT, 1990
Electricity Generating Authority of Thailand, *Annual report 1990,* Bangkok, 1990.

EGAT, 1991
Electricity Generating Authority of Thailand, "Thai - Lao power exchange to expand", *EGAT Newsletter,* vol. November - December 1991, pp. 4, Bangkok, 1991.

Energy Systems Group, 1987
Energy Systems Group, "Micro hydro power: training course for engineers and technicians: Volume 2 - Electrical", Report for the Intermediate Technology Development Group, Rugby, 1987.

Ernst and Young, 1990
Ernst and Young International, *Doing Business in Thailand,* New York, 1990.

ESCAP (a)
Economic and Social Commission for Asia and the Pacific, *Technology transfer: an ESCAP training module,* United Nations, Bangkok, undated.

ESCAP (b)
Economic and Social Commission for Asia and the Pacific, *Regional study on transfer of technology for small and medium industries,* United Nations, Bangkok, undated.

Etienne, 1990
Etienne, J. and Schadegg, M., "Ten years of experience of transfer of technology in Thailand", *Proceedings of the Fourth International Conference on Small Hydro,* pp. 354-364, International Water Power and Dam Construction, Sutton, 1990.

Evans, 1990
Evans, D.E., "The role of training in the development of small hydro projects", *Proceedings of the Fourth International Conference on Small Hydro,* pp. 283-295, International Water Power and Dam Construction, Sutton, 1990.

FAO, 1991
Food and Agriculture Organisation, "Vietnam - TFAP Fuelwood and energy sector review", *Wood Energy News,* vol. 6, no. 1, pp. 9, FAO, Bangkok, 1991.

Foley, 1989
Foley, G., *Electricity for rural people,* Rural Electrification Programme, Panos Institute, London, 1989.

Fraenkel, 1991
Fraenkel, P., et al., *Micro-hydro power - a guide for development workers,* IT Publications, London, 1991.

GATT Information Service, 1991
GATT Information Service, *GATT membership - May 1991,* General Agreement on Tariffs and Trade, Geneva, 1991.

Gilkes (a)
Gilbert Gilkes and Gordon, "Francis turbine", Product brochure of Gilbert Gilkes and Gordon, Kendal, undated.

Gilkes (b)
Gilbert Gilkes and Gordon, "Pelton turbine", Product brochure of Gilbert Gilkes and Gordon, Kendal, undated.

Gilkes (c)
Gilbert Gilkes and Gordon, "Turgo impulse turbine", Product brochure of Gilbert Gilkes and Gordon, Kendal, undated.

Gilkes (d)
Gilbert Gilkes and Gordon, "Turgo impulse turbine", Promotional diagram of Gilbert Gilkes and Gordon, Kendal, undated.

Gilkes, 1974
Gilbert Gilkes and Gordon, "Water turbines for hydro-electric power", Promotional brochure of Gilbert Gilkes and Gordon, Kendal, 1974.

Goldsmith, 1992
Goldsmith, K., "Some aspects of the privatisation of small-scale power schemes", *Hydronet,* vol. 3/92, pp. 10-11, Fördergesellschaft für Angepasste Techniken in der Dritten Welt (FAKT), Stuttgart, 1992.

Government of Lao PDR, 1989
Government of Lao PDR, "Report on the economic and social situation, development strategy and assistance needs of the Lao PDR - volume 1", Prepared for the round table meeting in Geneva, Government of Lao PDR, Vientiane, April 1989.

Green, 1991
Green, J.H., "The utilisation, dissemination and commercialisation of renewable energy systems in Pacific Rim Countries", PhD thesis, University of Edinburgh, 1991.

Hagler, Bailly and Company, 1986
Hagler, Bailly and Company, "Private-sector power generation in Thailand: Potential impediments and policy issues", Report prepared for USAID, Washington D.C., 1986.

Handley, 1993
Handley, P., "River of Promise", *Far Eastern Economic Review,* vol. 16th September 1993, pp. 68-70, 1993.

Hanoi Moi, 1991
Hanoi Moi, 11 November 1991.

Harris Hydroelectric
Harris Hydroelectric, "Harris hydroelectric systems", Promotional document of Harris Hydroelectric, Davenport, California, undated.

Ha Tien Luy, 1989
Ha Tien Luy, "Vietnam special: Small hydro power development in Vietnam", *SHP News,* vol. 3/89, pp. 13, Hangzhou Regional Centre for Small Hydro Power, China, 1989.

Helling, 1986
Helling, A.L., "Technology adaptation for development: Assessing Thailand's micro-hydro programme", Masters thesis, Asian Institute of Technology, Bangkok, 1986.

Henderson
Henderson, D.S., "Electronic load governor", Sales leaflet of Dr. Douglas Henderson, Napier University, Edinburgh, undated.

Hiebert, 1992 (a)
Hiebert, "Look to the north", *Far Eastern Economic Review,* vol. 6 August 1992, pp. 14-15, 1992.

Hiebert, 1992 (b)
Hiebert, "Barriers to Lao growth", *Far Eastern Economic Review,* vol. 6 August 1992, pp. 14-15, 1992.

Hiebert, 1992 (c)
Hiebert, "See-saw fortunes", *Far Eastern Economic Review,* vol. 14 May 1992, pp. 56-57, 1992.

Hislop, 1987
Hislop, D., "The micro-hydro programme in Nepal - a case study", Prepared for the IIED Conference on Sustainable Development for Intermediate Technology Development Group, Rugby, 1987.

Holland
Holland, R., "Economics of micro hydro power plants", Unpublished report, Intermediate Technology Development Group, Rugby, undated.

Hothersall, 1984
Hothersall, R., "Micro hydro: turbine selection criteria", *Water Power and Dam Construction,* vol. February 1984, pp. 26-29, 1984.

Houmphone Boulignaphonh, 1992
Houmphone Boulignaphonh, "L'électricité en République démocratique populaire lao (Laos)", *Actes du colloque Avenir de l'hydroélectricité au Cambodge, au Laos et au Viêt Nam,* pp. 563-579, Institut de l'Énergie des Pays ayant en commun l'usage du Français, Québec, 1992.

Huie, 1990
Huie, Soon Choon, Suling, B., "Small and mini hydro power development in Sarawak - an overview", *Proceedings of the Fourth International Conference on Small Hydro,* pp. 532-556, International Water Power and Dam Construction, Sutton, 1990.

Huq, 1993
Huq, M., "Industrialization in Bangladesh: Aid-dependence and failures of technology transfer", Paper presented at the Second International Conference on Science and Technology in Third World Development, Glasgow, 5-7 April 1993.

IMF, 1989
International Monetary Fund, *"Vietnam - recent economic developments",* Unpublished report, August 1989.

IREDA, 1992
Indian Renewable Energy Development Agency, "Guidelines for Loan Assistance", Leaflet of the IREDA, New Delhi ,1992.

Inversin, 1980
Inversin, A., *A pelton micro-hydro prototype design,* Research Series No.1, Appropriate Development Institute, Univerity of Technology, Papua New Guinea, 1980.

Inversin, 1986
Inversin, A., *Micro-hydropower sourcebook - a practical guide to design and implementation in developing countries,* NRECA International Foundation, Washington D.C., 1986.

Inversin, 1991 (a)
Inversin, A., "Visit to MCC demonstration micro-hydropower mills in Laos: findings and recommendations", Internal document of the International Programs Division of NRECA, Washington D.C., July 1991.

Inversin, 1991 (b)
Inversin, A., "Thoughts for a proposal for a micro-hydropower effort in Laos", Unpublished report, NRECA, Washington D.C., 19 December 1991.

ITDG, 1987
Intermediate Technology Development Group, "Micro hydro power - training course for engineers and technicians: Volume 1 - Civil and Mechanical", Unpublished report, ITDG, Rugby, 1987.

Jechoutek, 1992
Jechoutek, K.G., "Selection and economic viability of rural electrification projects", in *Rural Electrification Guidebook for Asia and the Pacific,* ed. G. Saunier, pp. 113-142, Asian Institute of Technology, Bangkok, 1992.

Jivacate Chaya
Jivacate Chaya , et al., "PV development in Thailand", Unpublished paper, Electricity Generating Authority of Thailand, Bangkok, undated.

Kabir-Ur-Rahman Khan, 1988
Kabir-Ur-Rahman Khan, "The UN code of conduct on transfer of technology", *Science, Technology and Development,* vol. 6, no. 1, pp. 5-12, Frank Cass, London, 1988.

LLN, 1988
Lembaga Lektrik Negara, "Malaysian experience in small hydro development", Unpublished paper, Lembaga Lektrik Negara, Kuala Lumpur, June 1988.

Lepiten, 1990
Lepiten, R., Scholz, L., "Implementing technology transfer and training", *Proceedings of the Fourth International Conference on Small Hydro,* pp. 331-353, International Water Power and Dam Construction, Sutton, 1990.

Leyland Consultants 1988
Leyland Consultants "Standardization of micro-hydro components for Thailand, Lao PDR and Vietnam", Unpublished report for the Interim Committee for Coordination of the Lower Mekong Basin, Bangkok, 1988.

Lucas, 1987
Lucas, N.J.D., et al., *Energy policy in Asia: A comparative study,* McGraw-Hill Book Company, Singapore, 1987.

Mallet, 1992
Mallet, V., "Bold investors size up 'next tiger'", *Bangkok Post,* 28 September 1992, pp. 20, 1992.

Manandhar, 1982
Manandhar, Amar Bahadur, "Planning rural electrification - The case of Thailand", Masters thesis, Asian Institute of Technology, Bangkok, 1982.

Mehm Thet San, 1991
Mehm Thet San, "New and renewable energy technologies development and utilization status in Myanmar", Paper presented at Asia Energy '91: The First Asia International Exhibition and Conference on New and Renewable Energy Information on Policy, Planning, Technology and Equipment, Bangkok, 17-20 October, 1991.

Meier, 1985
Meier, U., et al., *Local experience with micro-hydro technology,* Swiss Centre for Development Cooperation in Technology and Management (SKAT), St. Gallen, Switzerland, 1985.

Meinikheim, 1977
Meinikheim, B. F., *A working Peltonwheel,* Alternative Sources of Energy, Milaca, USA, 1977.

Meridian Corporation
Meridian Corporation, "Thailand: energy overview", Internal document prepared for the FINESSE project, Meridian Corporation, Alexandria, Virginia, undated.

Metzler, 1979
Metzler, R., "Problems encountered in designing and producing small scale water turbines in Nepal", Paper presented at the UNIDO Seminar-Workshop on the exchange of experiences and technology transfer on Mini Hydro Electric Generation Units, Kathmandu, Nepal, 10-14 September 1979.

Ministry of Trade and Tourism, 1992
Ministry of Trade and Tourism, *Export and import tariff for commercial goods,* Vietnam Trade Information Centre, Hanoi, 1992.

Minnot, 1981
Minnot, D., "Mini hydroelectric generation equipment considerations for local manufacture", Paper presented at the Caribbean Development Bank Mini-hydro Workshop by Dennis Minnot, Energy Development Division, SRC, Jamaica, March 1981.

Nakarmi, 1993
Nakarmi, K., Arter, A., Widmer, R., and Eiseming, M., *Cross flow turbine design and equipment engineering,* MHPG Series, vol. 3, Swiss Centre for Development Cooperation in Technology and Management (SKAT), St. Gallen, Switzerland, 1993.

NEA, 1990
National Energy Administration, *Electric power in Thailand 1990,* NEA, Bangkok, 1990.

Nelles Verlag
Nelles Verlag *South East Asia,* Map scale 1 : 4,000,000, Nelles Verlag, Munich, undated.

NESDB, 1992 (a)
National Economic and Social Development Board, *The Seventh National Economic and Social Development Plan (1992 - 1996),* Royal Government of Thailand, Bangkok, Thailand, 1992.

NESDB, 1992 (b)
National Economic and Social Development Board, "Mini and micro hydro plan for Thailand", Unpublished document, Royal Government of Thailand, Bangkok, 1992.

Ng, 1986
Ng, C., Hirono, R., and Siy, R., (ed.s), *Technology and skills in ASEAN - an overview,* Institute of Southeast Asian Studies, Singapore, 1986.

Nguyen Duc Loc, 1991
Nguyen Duc Loc, "New and Renewable Sources of Energy Application in Vietnam", Paper presented at Asia Energy '91: The First Asia International Exhibition and Conference on New and Renewable Energy Information on Policy, Planning, Technology and Equipment, Bangkok, 17-20 October, 1991.

Nguyen Duc Loc, 1992
Nguyen Duc Loc, "L'évaluation socio-économique de l'utilisation des petites centrales hydroélectriques au Viêt Nam", *Actes du colloque Avenir de l'hydroélectricité au Cambodge, au Laos et au Viêt Nam,* pp. 655-666, Institut de l'Énergie des Pays ayant en commun l'usage du Français, Québec, 1992.

Nguyen Huu Ninh, 1991

Nguyen Huu Ninh, Nguyen Minh Due & Hoang Minh Hien, "Greenhouse effect and energy development in Vietnam", Paper presented at the Conference on Greenhouse Research Initiatives in the ESCAP region, Economic and Social Commission for Asia and the Pacific, Bangkok, 21-23 August 1991.

Nguyen Khac Diem, 1992

Nguyen Khac Diem, "Small hydro development in Vietnam", *Proceedings of the Fifth International Conference on Small Hydro,* pp. 120-128, International Water Power and Dam Construction, Sutton, 1992.

Nguyen Thuong, 1990

Nguyen Thuong, "Development of Renewable Energy Sources", *Vietnamese Studies,* vol. 2/90, Vietnamese Studies, Hanoi, 1990.

Nguyen Van Hanh, 1992

Nguyen Van Hanh, "Rural Electrification in Vietnam", in *Rural Electrification Guidebook for Asia and the Pacific,* ed. G. Saunier, pp. 455-469, Asian Institute of Technology, Bangkok, 1992.

Nguyen Van Than, 1990

Nguyen Van Than, "Renewable Energy Research and application in Vietnam", Paper presented at the National Workshop on Renewable Energy in Vietnam, United Nations, Ho Chi Minh City, June 1990.

Nguyen Van Than, 1991

Nguyen Van Than, "Country paper: energy policy for rural development of Vietnam", Paper presented at Asia Energy '91: The First Asia International Exhibition and Conference on New and Renewable Energy Information on Policy, Planning, Technology and Equipment, Bangkok, 17-20 October, 1991.

NRECA, 1983

National Rural Electric Cooperative Association, *Small hydropower for Asian rural development,* NRECA, Washington D.C., 1983.

Ossberger

Ossberger, "Development and appraisal of mini hydro in remote areas", Promotional brochure, Ossberger, Weissenburg, Germany, undated.

Oud, 1993

Oud, E., & Crighton, P., "Hydropower in Lao PDR", *Water Power and Dam Construction,* vol. April 1993, pp. 38-41, Reed Business Publishing, Sutton, 1993.

Patent Office, 1986

Patent Office, *Introducing patents - a guide for investors,* Department of Trade and Industry, London, January 1986.

Phalasack Pheddara, 1992 (a)

Phalasack Pheddara, "Les petites centrales hydroélectriques et le ministère de l'Agriculture et des Forêts du Laos", *Actes du colloque Avenir de l'hydroélectricité au Cambodge, au Laos et au Viêt Nam,* pp. 581-588, Institut de l'Énergie des Pays ayant en commun l'usage du Français, Québec, 1992.

Phalasack Pheddara, 1992 (b)

Phalasack Pheddara, "Country paper: Lao People's Democratic Republic", Presented for the Department of Irrigation and Micro-hydropower at the Seminar on the Development of Small Scale Irrigation and Micro-hydropower, Vientiane, 3-5 November 1992.

Phan Khanh, 1992
Phan Khanh, "Présentation de l'entreprise mécanique Hydromec 276", *Actes du colloque Avenir de l'hydroélectricité au Cambodge, au Laos et au Viêt Nam,* pp. 699-706, Institut de l'Énergie des Pays ayant en commun l'usage du Français, Québec, 1992.

Pho Muangnalad, 1991
Pho Muangnalad, "Country paper: New and renewable energy in Lao PDR", Paper presented at Asia Energy '91: The First Asia International Exhibition and Conference on New and Renewable Energy Information on Policy, Planning, Technology and Equipment, Bangkok, 17-20 October, 1991.

Pinij Srangsriwong, 1985
Pinij Srangsriwong, "Micro/minielectric machinery manufacturing promotion for Thailand", Unpublished revised report for the National Energy Administration, Bangkok, 1985.

Prakob Wirojanagud, 1990
Prakob Wirojanagud, "The people's volunteer weir programme: a three way collaboration in irrigation", *Waterlines,* vol.8, no. 3, pp. 24-26, 1990.

Ramani, 1988
Ramani, K.V., ed., *Rural Energy Planning: Asian-Pacific Experiences,* Asia and Pacific Development Centre, Kuala Lumpur, 1988.

Ramani, 1992
Ramani, "Rural electrification and rural development", in *Rural Electrification Guidebook for Asia and the Pacific,* ed. G. Saunier, pp. 19-70, Asian Institute of Technology, Bangkok, 1992.

Randell, 1992
Randell, J., "The role of rural electrification in the development of Sarawak", PhD thesis, University of Edinburgh, 1992.

REDP, 1989
Regional Energy Development Programme, "Sectorial energy demand in Thailand", Unpublished report, REDP, Economic and Social Commission for Asia and the Pacific, Bangkok, November 1989.

REMIT Consultants, 1992
REMIT Consultants, *Vietnam - the next Asian tiger,* British Consultants Bureau, London, 1992.

Reungvith Vechasart, 1990
Reungvith Vechasart, "Renewable energy sources by Provincial Electricity Authority of Thailand", *Proceedings of the Seventh Asian School on Energy - Decentralised power production for the rural consumers,* pp. 178-184, Asian Institute of Technology, Bangkok, 1990.

Saetersmoen, 1992
Saetersmoen, G., "Xeset project increases generating capacity of Laos significantly", *Water Power and Dam Construction,* vol. October 1992, pp. 22-26, Reed Business Publishing, Sutton, 1992.

Sawad Hemkamol, 1990
Sawad Hemkamol, "NEA's experience in small hydro-power generation in Thailand", *Proceedings of the Seventh Asian School on Energy - Decentralised power production for the rural consumers,* pp. 68-73, Asian Institute of Technology, Bangkok, 1990.

Scheuer, 1980
Scheuer, H., Metzler, R. and Yoder, R., *Small water turbines,* Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ-GATE), Eschborn, Germany, 1980.

SHP News, 1988
SHP News, vol. 4/88, pp. 7, Hangzhou Regional Centre for Small Hydro Power, China, 1988.

SHP News, 1989
SHP News, vol. 2/89, pp. 5-6, Hangzhou Regional Centre for Small Hydro Power, China, 1989.

SHP News, 1990 (a)
SHP News, "Plastic conduits for small hydro", *SHP News,* vol. 1/90, pp. 23-25, Hangzhou Regional Centre for Small Hydro Power, China, 1990.

SHP News, 1990 (b)
SHP News, vol. 2/90, pp. 9, Hangzhou Regional Centre for Small Hydro Power, China, 1990.

SHP News, 1992
SHP News, vol. 2/92, pp. 7, Hangzhou Regional Centre for Small Hydro Power, China, 1992.

SHP News, 1993
SHP News, "Development of policies and programmes for small hydropower for developing countries, with special relevance to the Asia/Pacific region: a review of the last 15 years and possible future trends", *SHP News,* vol. 1/93, pp. 20-41, Hangzhou Regional Centre for Small Hydro Power, China, 1993.

Smith, 1990
Smith, "Stand-alone induction generators for reliable, low-cost micro-hydro installations", Paper presented at the First World Renewable Energy Congress, Reading, September 1990.

Sosthenes Buatsi, 1988
Sosthenes Buatsi, *Technology transfer - nine case studies,* IT Publications, London, 1988.

Sounthone, 1992
Sounthone, "New Hydro-power project of Laos", *Laos,* vol. 1/92, Vientiane, 1992.

Stewart, 1979
Stewart, F., *International technology transfer: issues and policy options,* World Bank Staff Working Papers No.344, World Bank, Washington D.C., 1979.

Sumphorn Manodham, 1992
Sumphorn Manodham, "Rural electrification in Laos", in *Rural Electrification Guidebook for Asia and the Pacific,* ed. G. Saunier, pp. 381-394, Asian Institute of Technology, Bangkok, 1992.

Tang, 1982
Tang, J. and Ho, W., "ASEAN-EC: Joint ventures: A case study of promoted firms in Thailand", Paper presented at the Conference on ASEAN-EC Economic Relations, ASEAN Economic Research Unit, Institute of South-East Asian Studies, Singapore 1982.

TDRIF, 1991
Thailand Development Research Institute Foundation, "Industrializing Thailand and its impact on the environment", in *Energy and environment: choosing the right mix,* Research report no. 7, TDRIF, Bangkok, 1991.

Tran Quoc Cuong, 1992
Tran Quoc Cuong, "La politique nationale du développement de l'hydroélectricité au Viêt Nam", *Actes du colloque Avenir de l'hydroélectricité au Cambodge, au Laos et au Viêt Nam,* pp. 603-638, Institut de l'Énergie des Pays ayant en commun l'usage du Français, Québec, 1992.

Twidell, 1986
Twidell, J., and Weir, T., *Renewable energy resources,* University Press, Cambridge, 1986.

UN

United Nations, *Regional new and renewable sources of energy development programme for Asia and the Pacific - Proceedings of the high-level regional consultative meeting for the mobilization of financial resources for new and renewable sources of energy, and of the meeting of focal points on new and renewable sources of energy,* United Nations, Bangkok, undated.

UN, 1988

United Nations, *New and renewable sources of energy for development,* Energy resources development series no. 30, UN Publications, Bangkok, 1988.

UN, 1990 (a)

United Nations, *Traders' manual for Asia and the Pacific - Thailand,* United Nations, New York, 1990.

UN, 1990 (b)

United Nations, *Least developed countries of Asia and the Pacific Region: development performance and prospects - Volume 1,* United Nations, New York, 1990.

UN, 1990 (c)

United Nations, *Report on the technological rehabilitation of small-scale foundries in the ESCAP region,* United Nations, New York, 1990.

UN, 1991

United Nations, *Traders' manual for Asia and the Pacific - Lao People's Democratic Republic,* United Nations, New York, 1991.

UN, 1992 (a)

United Nations, *Sectoral Energy Demand in Vietnam,* United Nations, Bangkok, 1992.

UN, 1992 (b)

United Nations, *Sectorial energy demand in Lao People's Democratic Republic,* United Nations, 1992.

UNCTAD, 1986

United Nations Conference on Trade and Development, *Transfer, adaption and diffusion of mature renewable energy technologies in developing countries,* UNCTAD, Geneva, 1986.

UNCTAD, 1989

United Nations Conference on Trade and Development, *Technology policy in the energy sector: issues, scope and options for developing countries,* UN Publications, Geneva, 1989.

UNCTAD, 1992

United Nations Conference on Trade and Development, *Periodic report 1990: Policies, laws and regulations on transfer, application and development of technology,* United Nations, New York, 1992.

UNCTC, 1987

United Nations Centre on Transnational Corporations, *Technology acquisition under alternative arrangements with transnational corporations: selected industrial case studies in Thailand,* Series A, no. 6, UNCTC Current Series, United Nations, New York, 1987.

UNDP, 1986

United Nations Development Programme, "Project document: Testing and improvement of waterturbine performance", Internal report VIE/86/041, UNDP, Hanoi, 1986.

UNDP, 1990

United Nations Development Programme, "Report on the economy of Vietnam", Unpublished draft copy of report, UNDP, Bangkok, 1990.

UNDP, 1993
United Nations Development Programme, *Human development report 1993,* Oxford University Press, Oxford, 1993.

UNIDO, 1977,
United Nations Industrial Development Organization, *National approaches to the acquisition of technology,* Development and Transfer of Technology Series no.1, United Nations, New York, 1977.

UNIDO, 1983
United Nations Industrial Development Organization, *Small hydropower series No.1: Mini-hydropower stations - A manual for decision makers,* United Nations Publications, New York, 1983.

UNIDO, 1985
United Nations Industrial Development Organization, "Development of electric power equipment sector and technology unpackaging: (background document to issue II)", Document no. ID/WG.442/4, UNIDO, 1985.

UNIDO, 1988
United Nations Industrial Development Organization, "Technical report: Assistance to the Institute of Electrical Science and Technology for testing and improving water turbine performance", Unpublished document DP/VIE/86/041, UNIDO, Vienna, 1988.

USAID, 1982
United States of America Overseas Aid Organisation, "Micro/mini hydroelectric project", Project paper annexes, Annex B, IV: Power Plant Analysis, Project no. 493 - 0324, USAID for the National Energy Administration, Bangkok, September, 1982.

Viengxay Souvannakhot, 1992
Viengxay Souvannakhot, "Le rôle de l'Institut national polytechnique dans la formation des ingénieurs", *Actes du colloque Avenir de l'hydroélectricité au Cambodge, au Laos et au Viêt Nam,* pp. 589-596, Institut de l'Énergie des Pays ayant en commun l'usage du Français, Québec, 1992.

Vietnam Investment Review, 1992
Vietnam Investment Review, "World Bank team scrutinises pressing energy problem", *Vietnam Investment Review,* vol. 16-22 March, Hanoi, 1992.

Vo Sy Huynh, 1990
Vo Sy Huynh, "Etudes et trace de turbines pour des microcentrales hydroélectriques au Vietnam", *Séminaire Franco-Vietnamien sur la planification énergétique, formation et coopération,* pp. 381-394, Centre International de Formation en Politique Énergétique, Paris, 1990.

Wallace, 1990
Wallace, "Small-scale hydro power generation", PhD thesis, University of Edinburgh, 1990.

Waltham, 1992
Waltham, M., "Pelton wheels 'Made in Nepal'", *Hydronet,* vol. 2/92, pp. 11-12, Fördergesellschaft für Angepasste Techniken in der Dritten Welt (FAKT), Stuttgart, 1992.

Weir Pumps
Weir Pumps, "Small hydro power generation", Promotional brochure, Weir Pumps, Glasgow, undated.

Whitby, 1984
Whitby, G., "Electronic load-controlled mini-hydroelectric projects: Experiences from Colombia, Sri Lanka and Thailand", in *Blending the new and traditional technologies - case studies,* ed. A. Bhaua, D. James, and Y. Stevens, pp. 121-134, International Labour Organisation, 1984.

pc: Nguyen Duc Loc (d)
Discussion with Mr Nguyen Duc Loc, Deputy Executive Secretary, National Programme on New and Renewable Sources of Energy of Vietnam, Hanoi, and owners of Family-hydropower equipment, Dong Nai province, 9 October 1992.

pc: Pakse
Information obtained in visits to shops in Pakse, Champassak province, 27 November 1992.

pc: PMWWC
Fax from P.M. World Wide Corporation Limited, Bangkok, to the Ministry of Agriculture and Forestry, Vientiane, 20 October 1989.

pc: Preecha
Telephone discussion with Mr Preecha Watanakunakorn, Managing Director, Pornpat Engineering Company, Bangkok, 13 January 1992.

pc: Preston
Discussion with Mr D Preston, Royds Garden Limited, Christchurch, in Vientiane, 2 December 1992.

pc: Prida Wibulswas
Discussion with Professor Prida Wibulswas, King Mongkut's Institute of Technology, Thonburi, Bangkok, 13 January 1992.

pc: Tran Hoang Chinh
Meeting with Mr Tran Hoang Chinh, Vice Director, Machine Tools Factory Number One, Hanoi, 16 October 1992.

pc: Viengsavana
Discussion with Mr Viengsavana, Head of Economics Affairs to the Provincial Cabinet, Saravan, 28 November 1992.

pc: Viraphanh Nandavong
Discussion with Mr Viraphanh Nandavong, Department of Micro-hydropower, Ministry of Industry and Handicrafts, Vientiane, 23 November 1992.

APPENDIX A: LIST OF PEOPLE WITH WHOM DISCUSSIONS WERE HELD

VIETNAM

Prof. Nguyen Duc Loc, Deputy Executive Secretary,
National Programme on New and Renewable Sources of Energy, HANOI.

Prof. Nguyen Cong Van, Vice Director &
Prof. Dr. Vo Sy Huynh, Vice Director,
Renewable Energy Research Centre, HANOI.

Mr. Preben Hjortlund, Deputy to the Country Director &
Mr. Tran Trong Phung, Programme Officer,
UNIDO, HANOI.

Ms. Nguyen Minh Tam, Programme Officer,
Vietnam National Mekong Committee, HANOI.

Mr. Nguyen Duy Tam, Deputy Director &
Mr. Nguyen Van Ty,
Electrical Equipment Designing Enterprise, HANOI.

Mr. Le Duc Minh, Assistant Manager,
Machino-import, HANOI.

Prof. Dr. Phan Ky Nam, Head of the Faculty of Hydro-electricity, &
Prof. Ngo Dinh Tuan, Head Dep. Hydrology & Water Resources Planning, &
Dr. Nguyen Van Thang, Lecturer of Hydrology, &
Dr. Bui Cong Quang, Faculty of Hydrology,
Water Resources University, HANOI.

Mr. Le Ba Nhung, Manager, Hydropower Division No.1,
Power Investigation and Design Company No.1, HANOI.

Mr. Ha Tien Luy, Director of Dep. of Hydro-power, &
Mr. Do Thiet Hung, Dep. of International Co-operation, &
Mr. Nguyen Van Chung, Head of Dep. of International Co-operation,
Institute of Energy, Ministry of Energy, HANOI.

Hydro-power Equipment Centre, Ministry of Water Resources, HANOI.

Mr. Hoang Van Thang, Director,
Inst. for Hydraulic Research, Hydro Electric Research Centre, HANOI.

Mr. Long, Hydro-power Governor Specialist,
Governor Research Enterprise, HANOI.

Prof. Hoang Dinh Tin, Vice Director, &
Mr. Nguyen Nhut, Factory Chief,
Research Centre for Thermal Research & Renewable Energy, HO CHI MINH CITY.

Mr. Nguyen Van Muoi, Director,
Mechanical Engineering Factory, Min. of Heavy Industry, HO CHI MINH CITY.

Ms. Marie Louise Hoogveld, Deputy Representative,
CIDSE, HANOI.

Mr Hoang Van Thong,
Office of Science and Technology, DONG NAI PROVINCE.

Mr. Cuong, Project Manager,
Suoi Vang Hydro-power Project, LAM DONG PROVINCE.

Mr. To Van Thai, Director,
Centre for Science and Technology, BINH DINH PROVINCE.

Mr. Nguyen Kong, Office of Water conservancy,
Dep. of Irrigation and Hydro-power, BINH DINH PROVINCE.

Prof. Tang Thien Tu, Director,
Electrical and Electronic Research Centre, DANANG.

Mr. Le Van Hoang, Vice Rector,
Danang Polytechnic University, DANANG.

Dong Anh Electrical Equipment Factory, HANOI.

Mr. Tran Hoang Chinh, Vice Director,
Machine Tool Factory No.1, HANOI.

Mr. Cong, Marketing and Planning Production,
Dong Anh Factory, HANOI.

Ms. Nguyen Phuong Nhi, Project Officer,
Save the Children Fund (U.K.), HANOI.

LAO PDR

Mr. Sivath Soneythavy, Deputy Director, &
Mr. Phalasack Pheddara, Deputy Director,
Institute of Irrigation and Micro-hydropower,
Ministry of Agriculture and Forestry, VIENTIANE.

Mr. Viraphanh Nandavong, Department of Micro-hydropower,
Ministry of Industry and Handicrafts, VIENTIANE.

Mr. Outhai Oudavong, Deputy Manager of Project Department,
Electricite du Laos, VIENTIANE.

Mr. Kaysone Vongkhamheng, Chief of Irrigation and Micro-hydro,
Provincial Office of Ministry of Agriculture and Forestry, LUANG PRABANG.

Mr. Viengthong Phommahaxay, Chief Irrigation and Micro-hydro Service,
Provincial Office of Ministry of Agriculture and Forestry, SARAVAN.

Mr. Viengsavana, Head of Economic Affairs,
Provincial Cabinet, SARAVAN.

Mr. Narongsack Sayakounh, Chief,
Department of Foreign Relations, CHAMPASSAK.

Mr. Lam Ngeunh Phakaysone, Managing Director,
Techno Phatthana Khetpoudoi, VIENTIANE.

THAILAND

Mr. Virayut Sujirakulkit, Manager, &
Mr. Chanchai Limpiyakorn, Technical Director,
Ms. Suporn, Representative in Chiang Mai,
Appropriate Technology Association (ATA), BANGKOK.

ASEAN Sub Committee on Non-Conventional Energy Research, BANGKOK.

Mr. Prida Thiamakorn, Director, Regional Research and Development Centre,
Asian Institute of Technology (AIT), BANGKOK.

Dr. Norkun Sittipong, Head of Department, &
Mr. Prapan Siriplabpla,
Department of Mechanical Engineering, Chiang Mai University, CHIANG MAI.

Mr. Guangchang Shi, Chief, Natural Resources Division (NRD), &
Dr. Kyi Lwin, Economic Affairs Officer, NRD, &
Mr. Budi Sudarsono, Chief, Energy Resources Section, NRD, &
Mr. Gerard Saunier, NRD, &
Mr. Filino Harahap, Regional Energy Development Programme,
Economic and Social Commission for Asia and the Pacific (ESCAP), United Nations, BANGKOK.

Mr. Sarit Sasnanan, Chief, Hydro Power Plant Division, &
Mr. Chai Chuvakiet,
Electricity Generating Authority of Thailand, BANGKOK.

Energy Research and Training Centre, Chulalongkorn University, BANGKOK.

Professor Prida Wibulswas, Head of School of Energy and Materials, &
Dr. Morakot Tanticharoen,
King Mongkut's Institute of Technology Thonburi (KMITT), BANGKOK.

Mr. Hayao Adachi, Hydro Power Engineer,
Mekong Secretariat, BANGKOK.

Mr. Chaiyasit Thungsirispin, Micro-hydropower Manager, &
Mr. Wichien Rungwatanaporn, &
Mr. Sawad Hemkaman, Design Department, &
Mr. Niyom Maprajong,
Department of Energy Affairs (DEA), BANGKOK.

National Energy Information Centre, BANGKOK.

Mr. Choke, Manager,
Mining and Industrial Machines Workshop, CHIANG MAI.

Mr. Tepawan Wattanaprateep,
PANYA Consultant Company Ltd, BANGKOK.

Project for Ecological Recovery, BANGKOK.

Mr. Porphol Yamchinda,
Promotion of Appropriate Technology Group (PAT), BANGKOK.

Dr. Chulapongs Chullakesa, Deputy Governor (Operations), &
Mr. Wiranit, &
Mr. Martin Hartley, Balfour Beatty Representative,
Provincial Electricity Authority (PEA), BANGKOK.

Mr. Preecha Watanakunakorn, Managing Director,
Pornpat Engineering Company Ltd, BANGKOK.

Professor Thamrong Prempridi, Dean,
Faculty of Engineering, Rangsit University, BANGKOK.

Regional Energy Resource Information Centre (RERIC), AIT, BANGKOK.

Mr. Sumitr Pitiphat, Dean of Sociology and Anthropology,
Thamasat University, BANGKOK.

United Nations Development Program (UNDP), BANGKOK.

APPENDIX B: TECHNICAL VISITS TO FACTORIES

Hydro-power Equipment Centre, Ministry of Water Resources, HANOI.

Institute for Hydraulic Research, Hydro Electric Research Centre, HANOI.

Hydraulic test centre of the Hanoi Polytechnic University, HANOI.

Dong Anh Electrical Equipment Factory, HANOI.

Machine Tool Factory No.1, HANOI.

Mechanical Engineering Factory, Ministry of Heavy Industry, HO CHI MINH CITY.

Factory of the Research Centre for Thermal Research & Renewable Energy,
HO CHI MINH CITY.

Irrigation and Micro-hydropower Equipment Factory, VIENTIANE.

Agricultural Tools Making Factory, VIENTIANE.

Workshop on the Luang Prabang Road, VIENTIANE.

Promotion of Appropriate Technology, BANGKOK.

Mining and Industrial Machine Shop, CHIANG MAI.

APPENDIX C: HYDROPOWER SCHEMES VISITED

Tien Yen District, Quang Ninh Province, VIETNAM, (200kW).

Song Rai village, Xuan Loc District, Dong Nai Province, VIETNAM,
(100W, 1kW & 12kW).

Bao Loc project, Lam Dong Province, VIETNAM, (3 x 200kW).

Suoi Vang Hydro-power Project, Lam Dong Province, VIETNAM,
(2 x 1.25MW & 2 x 300kW).

Nu Mot project, An Nhon District, Binh Dinh Province, VIETNAM, (240kW).

Houay Nam Si, Pathoumphone, Champassak, LAO PDR, (8.5kW).

Ban Phak Kout, Lao Ngam District, Saravan, LAO PDR, (25kW).

Ban Tha Paen, Luang Prabang, LAO PDR, (11kW & 5kW).

Huai Pa Thao scheme, Chaiyaphum, THAILAND, (2.3MW).

Doi Lang, Fang District, Chiang Mai, THAILAND, (60kW).

Huay Somsuk Village, Chiang Mai, THAILAND, (7kW).

Kampong Project, San Kampaeng District, Chiang Mai, THAILAND, (20kW).

Mae Thun Noi, Om Koi District, Chiang Mai, THAILAND, (250kW).

Muangka Village, Chiang Mai, THAILAND, (10kW)

Pang Hai, Chiang Mai, THAILAND, (40kW).

Mae Sa, Chiang Mai, THAILAND, (2x650kW).

Mae Ka Min, Kanchanaburi, THAILAND, (30kW).

APPENDIX D: COUNTRY CATEGORISATION

In accordance with the United Nations categorisation [UNDP, 1993].

Industrialised countries

Albania	Greece	New Zealand
Armenia	Hungary	Norway
Australia	Iceland	Poland
Austria	Ireland	Portugal
Azerbaijan	Israel	Romania
Belarus	Italy	Russian Federation
Belgium	Japan	Spain
Bulgaria	Kazakhstan	Sweden
Canada	Kyrgyzstan	Switzerland
Czechoslovakia	Latvia	Tajikistan
Denmark	Lithuania	Turkmenistan
Estonia	Luxembourg	Ukraine
Finland	Malta	United Kingdom
France	Moldova, Rep. of	U.S.A.
Georgia	Netherlands	Uzbekistan
Germany		

All other countries are classified as 'developing countries'.

APPENDIX E: ORGANISATIONS OFFERING TECHNOLOGY TRANSFER ADVICE AND SERVICES IN SOUTH-EAST ASIA

Technology Transfer Services,
Economic and Social Commission for Asia and the Pacific,
IHE Division,
United Nations Building,
Rajdamnern Avenue,
Bangkok 10200,
Thailand.

Trade Promotion Centre,
International Trade and Tourism Division,
ESCAP,
United Nations Building,
Rajdamnern Avenue,
Bangkok 10200,
Thailand.

Consultancy Centre for Technology Transfer and Investment,
No. 34 Ly Thuong Kiet St.,
Hanoi,
Vietnam.

INVESTCONSULT,
Investment Consultancy and Technology Transfer Company,
No. 16 Thuy Khue St.,
Hanoi,
Vietnam.

Asian and Pacific Centre for the Transfer of Technology,
Manickvelu Mansion,
49 Palace Road,
Bangalore 560052,
India.

German Appropriate Technology Exchange (GATE/GTZ),
P.O. Box 5180,
6236 Eschborn 1,
Germany.

Asian Network for Industrial Information and Extension,
TECHNONET,
Owen Road, P.O. Box 0165,
Singapore 9121.

Technology Information Exchange System,
Technology Group UNIDO,
P.O. Box 300,
Vienna International Centre,
1400 Vienna,
Austria.

Industrial and Technological Information Bank,
UNIDO,
P.O. Box 300,
Vienna International Centre,
1400 Vienna,
Austria.

APPENDIX F: PUBLISHED REFEREED PAPER BASED ON THE WORK OF THIS THESIS

Published in the book:
Technology and developing countries, Frank Cass, London, 1994.

TECHNOLOGY TRANSFER FOR LOCAL MANUFACTURE OF MINI AND MICRO HYDROPOWER EQUIPMENT WITHIN VIETNAM, THAILAND AND THE LAO PDR

J P Green, D E Macpherson, A R Wallace,

Energy Systems Group,

Department of Electrical Engineering,

University of Edinburgh.

ABSTRACT

The three Mekong Basin riparian countries of Thailand, Vietnam and the Lao People's Democratic Republic (PDR), situated in South-East Asia, are experiencing many economical and political changes which are creating new opportunities for cooperation and trade. Thailand has developed over 15 mini-hydro (between 200kW and 2MW) and over 50 micro-hydro (less than 200kW) schemes, with most of the equipment for those schemes, with capacities of less than 100kW, being locally manufactured. In Vietnam approximately 3,000 family-hydro (between 50W and 1kW) and micro-hydro generators have been installed, whilst in the neighbouring Lao PDR, where less than 5% of the population have access to electricity, fewer than 20 micro-hydro schemes are in operation.

This paper illustrates how each country can benefit from the local manufacture of mini-hydro and micro-hydro equipment. It begins by describing the history and present day situation concerning small-scale hydro developments and local manufacturing capabilities in the three countries. This is followed by a discussion of the effects which international cooperative projects and non-governmental organisation involvement in small-scale hydro development have had and are likely to have in the future. It is suggested that by sharing experience and expertise, implementing organisations in the Lao PDR will be able to learn from the successes and failures of similar efforts of its two neighbouring countries, during the initial stages of its micro-hydro development. An explanation is made of how villages in Thailand which are not likely to be electrified under existing programmes, may be able to benefit from cheaper equipment presently being used in Vietnam.

1. INTRODUCTION

Micro-hydro equipment has widely been used for rural electrification and in many cases has been able to provide an effective way to provide electricity - especially to isolated communities. Equipment manufactured locally benefits the local economy, is often cheaper, and can more readily be designed to suit local conditions.

The changing atmosphere in the relations between Thailand and Vietnam and the progressively improving relations over the last few years between Thailand and the Lao PDR, are presenting new opportunities for increased cooperation in the region. Each of the countries has manufactured small-scale hydropower equipment, but with different levels of success. There is now the prospect of a greater exchange of experience and technology in order to strengthen the local manufacturing industry and promote the use of mini-hydro and micro-hydro power. International cooperation has been of great importance in the dissemination of information about renewable energy technologies [UNCTAD Secretariat, 1990].

This paper will review the situation concerning the development of mini-hydro and micro-hydro power in each of the three countries, and will discuss the prospects for increased local manufacture and cooperation in the region.

2. THAILAND

2.1. Rural electrification

Thailand, with an area approximately the size of France (513,000 sq. km) has a population of 56.3 million people (1990). By the end of 1991 approximately 94% of the 61,205 villages in Thailand had been electrified, and the Provincial Electricity Authority (PEA)† presently has plans to achieve 98% rural electrification by 1996 [Chulapongs Chullakesa, 1992]. This will still leave approximately 1,200 villages without electricity. Many of these remaining villages are situated in the highlands, some in National Parks and others on islands, and all are distant from existing transmission lines. It is considered by the PEA that it will be uneconomical to provide electricity to many of these villages, and that 'total electrification of Thailand' could be considered to have been implemented once 98% of the villages are electrified [Chulapongs Chullakesa, 1992]. This would still compare favourably with the situation in other countries. If the remaining villages are to receive an electricity supply, then alternative supply solutions must be found, or the cost of existing options must be reduced.

The Department of Energy Affairs (DEA)* has also developed several grid independent rural electrification schemes, as have several non-governmental organisations (NGO).

2.2. Mini-hydro and micro-hydro developments

Presently micro-hydropower is under the auspices of the Department of Energy Affairs. They are nearing the completion of a government sponsored micro-hydro programme for 75 schemes, and they have also been the initiators of several mini-hydro schemes, which are envisaged to come under the management of the PEA.

Micro-hydro was effectively introduced to northern Thailand in the late 1970's. So far over 50 micro-hydro (less than 200kW) and 15 mini-hydro (between 200kW and 2MW) schemes have been developed, mainly in the north of the country. A 'Masterplan' presently being prepared will assess a further 300 sites of up to 200kW, and it is envisaged that up to 30 of these will proceed to a detailed site investigation. The majority of those sites which are eventually constructed are likely to be supplied with turbines manufactured by the Mining and Industrial Machine Workshop based in Chiang Mai.

The PEA is operating 3 mini-hydro generating stations and is in the process of building a further 5, to provide an overall capacity of 18MW. To initiate their programme the PEA appealed for international assistance in order to gain experience in the evaluation, planning, design, construction, operation and maintenance of mini-hydro schemes. Norway was the first to offer technical assistance by covering the cost of consultancy services, training and electro-mechanical equipment for two projects. The UK were the second country to give assistance which also covered the cost of consultancy service, electro-mechanical equipment and training [Chulapongs Chullakesa, 1991]. By the end of their training Thai engineers were then able to design the third UK funded scheme themselves.

---

† The PEA is responsible for supplying electricity through the distribution system to the provinces outside of Bangkok.

* The Department of Energy Affairs has taken over most of the responsibilities of the disbanded National Energy Authority (NEA).

The PEA estimate the cost of production of electricity from mini-hydropower to be 0.65-0.99 Baht/kWh (£0.016-£0.025/kWh), compared with 1.04 Baht/kWh (£0.026/kWh) purchased from the main generating organisation EGAT and as much as 5.00 Baht/kWh (£0.125/kWh) from diesel sets [Chulapongs Chullakesa, 1992].

Thailand has a relatively well coordinated infrastructure for micro-hydro development, but it is generally considered that the need for more micro-hydro schemes is diminishing. One of the criticisms of the major organisations involved has been that they are not particularly concerned with cost effectiveness [Brown]. Schemes have in general been expensive to construct, though the infra-structure set up to maintain these sites has been very effective.

2.3. Local manufacture

Local manufacture of micro-hydro equipment in Thailand started initially with the purchase and replication of an imported Chinese turbine/generator/governor set [Helling, 1986]. Following this, in the late 1970's, a crossflow turbine was designed from first principles by a Thai engineer with the help of funding from the National Research Council of Thailand. The turbine design was characterised not only by both good efficiency and durability, but also ensured that the manufacture of the runner, guide vanes and housing were within the capability of typical, well-equipped Thai machine shops [Helling, 1986]. After one year in the laboratory and workshop, a 7.5kW design attached to a Chinese generator was installed at an isolated site. The Mining and Industrial Machine Workshop based in Chiangmai were then commissioned by the disbanded National Energy Administration (NEA) to manufacture crossflow micro-hydro turbines, and they are presently the only manufacturers of turbines in the country.

The next design was fabricated by a large commercial machine shop in Bangkok. Both the generator and the governor were imported for this 180kW project. They were then requested by the NEA to help develop turbine manufacturing capabilities with the aim that Thailand become an exporter of the equipment to the Association of South-East Asian Nations (ASEAN) region. To begin with, an agreement was made with a French company, to import some of the turbine components, whilst more than 50% of the equipment was to be locally manufactured. The static components, which included spiral casing, draft tube, frame and guide vanes for the Francis turbines were all manufactured in Bangkok, as were generators, stainless-steel parts and bearing sub-assemblies [Helling, 1986]. For the Pelton turbines all parts were manufactured in Thailand except for runners and nozzles [Etienne & Schadegg, 1990]. The workshop, which produced 12 turbines is no longer manufacturing hydro equipment. As yet no complete reaction turbine has been designed and manufactured in Thailand.

The Chiangmai workshop is also capable of Pelton turbine fabrication, but as yet they have not had any installed. For many years they have been making cross-flow turbines for the NEA's micro-hydro schemes and their equipment has proved to be reliable and relatively cheap. A 40kW machine designed for a 50m head would cost approximately 370,000 Baht (£8,200) including turbine, turbine and generator mountings and flywheel. This is substantially cheaper than any European equipment.

Presently most of the equipment for those schemes with capacities of less than 100kW are being locally manufactured, whilst the majority of mini-hydro equipment is imported from China, Britain and France. An NGO, the Appropriate Technology Association (ATA) has manufactured its own cross-flow turbines based upon a published design.

Governing of most micro-hydro schemes in Thailand is via Electronic Load Control (ELC). In 1980 a prototype ELC was offered by the Intermediate Technology Development Group (ITDG) and they are now assembled at an NEA's workshop. An ELC was also designed and produced by the ATA, with the experience gained by one of their engineers whilst in Nepal [ATA, 1987].

The turbines developed by the NEA and presently manufactured in Chiangmai, and the ELCs which are locally made, have reduced equipment costs to half of those previously encountered for imported equipment [UN, 1988].

3. VIETNAM

3.1. Rural electrification

With an area of 329,600 sq. km Vietnam extends 1,630 km from its northern to southern most tips. Of the 65 million population, approximately 75% live in rural areas [Nguyen Duc Loc, '91] and in these rural areas 10-15% of the households are electrified. The annual electricity consumption per capita for the country as a whole, is as low as 20kWh [Saunier, 1992]. 12 million people live in areas where there are no plans for grid extensions from the existing distribution system due to cost. Many of these people live in isolated and hilly regions of the country, and government policy for these areas is in favour of the development of small-scale hydro schemes.

In many of the regions where there is no grid connection, the use of car batteries and other 12V batteries, charged via diesel generators, is widespread [Cromwell & Pandey, 1991]. The cost of electricity in the cities is 250 dong/kWh (£0.016/kWh), and is usually much higher in rural areas where the tariff is dependant upon the extent of losses in the local system.

3.2. Mini-hydro and micro-hydro developments

There are about 2,400 rivers (greater than 10km long) in Vietnam [Saunier, 1992]. At present one million people in 20 highland Provinces receive electricity from small-scale hydropower stations.

By 1975, 264 micro-hydro schemes and a further 26 mini-hydro schemes had been constructed. In the years between 1975 and 1985 a further 92 micro-hydro schemes and 18 mini-hydro schemes were installed [SHP News, 1989]. At present there are approximately 400 micro-hydro and mini-hydro schemes and in addition, approximately 3,000 family-hydro sets with capacities between 50W and 1kW. The Institute of Energy in Vietnam believes there to be a further 2,500 economically feasible micro-hydro and 500 mini-hydro sites in the country [Ha Tien Luy, 1989].

It is estimated that approximately half of the sites constructed to date are now no longer operating, mainly due to the scarcity of funds for maintenance and the lack of consideration given to the supply of spare parts. In the Bac Thai Province, for example, 22 out of the existing 35 installations are no longer operating due to mechanical disrepair compounded by lack of financial resources [Cromwell and Pandey, 1991].

Family-hydro installations, which comprise of 50W - 1kW turbine and generator, are being used widely and have the advantage of being installed by family members with little or no outside assistance [Cromwell & Pandey, 1991]. These can be purchased in the market place, for as little as US$28 for a turbine and generator which will supply in the region of 80W. There are estimated to be as many as 3,000 of these in operation, mainly in the north of the country. The most popular equipment operates from a 1.5 - 2.5 metre head, generating approximately 200W of electricity for a purchase price of US$75 (the per capita annual income for a typical Vietnamese is between US$150 & US$200). A 1kW unit which operates from a 2m head has been shown to have a payback period of under a year when the electricity is sold within the village [Nguyen Duc Loc, 1991].

TURBINE TYPE	ORIGIN	POWER (W)	HEAD (m)	FLOW RATE (cubic m/s)	COST IN VIETNAM (US$)
PROPELLER	CHINA	100	1 - 2	0.015	28
PROPELLER	VIETNAM	200	1.5 - 2.5	0.020	75
TURGO	CHINA	250	6 - 15	0.005	32
PROPELLER	VIETNAM	1,000	2 - 4	0.080	350

TABLE 1: Some family-hydro equipment available in Vietnam

One of the main failures of the Vietnamese approach has been the lack of provision for financial security to pay for project repair. With approximately half of the schemes in a state of disrepair, it is evident that repair and maintenance will have to become a priority if their use is to become a reliable supply option. Also, funding will be required to bring those disrepaired sites into operation.

3.3. Local manufacture

Until 1975 all the small-scale hydro equipment installed in Vietnam was imported. Much of the equipment is still being imported from China, though since that time several organisations have manufactured Francis, Kaplan, Pelton and crossflow turbines within Vietnam [Ha Tien Luy, 1989].

Vietnam has developed its manufacturing capabilities by copying foreign equipment, mainly Chinese, and in some cases improving upon it. Many schemes have been set up without significant foreign assistance, and several of these have been exported to the Lao PDR and Mongolia [Nguyen Khac Diem, 1992].

Table 2 shows the capabilities and experience of the main turbine producing organisations within Vietnam. The Machine Tool Factory No.1 in Hanoi is no longer producing hydro-power components, primarily because the quality of their equipment was poor, and many of the sites established are no longer operating. This was due to the quality of the metal used being poor, high volumes of silt eroding the blades, and a general lack of expert knowledge within the company for designing high quality and high efficiency blades.

FACTORY	TURBINES MANUFACTURED	CAPACITIES OF TURBINES	PRESENTLY PRODUCING	COMMENTS
MACHINE TOOL FACTORY No. 1	FRANCIS, KAPLAN & PELTON	20 - 1,500kW	NO	PROBLEMS WITH METAL QUALITY AND TURBINE EFFICIENCY.
DONG ANH ELECTRICAL EQUIPMENT FACTORY	FRANCIS, KAPLAN, BANKI & PROPELLER	5 - 2,000kW	NO	PROBLEMS WITH METAL QUALITY & TURBINE EFFICIENCY. PRODUCED APPROX 200 TURBINES BETWEEN 1983 &1988.
HYDRO ELECTRIC RESEARCH CENTRE	FRANCIS	UP TO 200kW	YES	OVER 10 SCHEMES SO FAR PRODUCED. GOOD TURBINE EFFICIENY & RELIABILITY, THOUGH TURBINES ONLY HAVE 3 YEARS IN OPERATION.
ELECTRICAL EQUIPMENT DESIGNING ENTERPRISE	FRANCIS, KAPLAN, PELTON & BANKI	10 - 2,100kW	YES	OVER 20 SCHEMES MANUFACTURED. 5 SCHEMES INSTALLED LAST YEAR.
RENEWABLE ENERGY RESEARCH CENTRE	FRANCIS & FAMILY HYDRO	200W - 1,250kW	YES	MAINLY PRODUCES 200W & 1kW FAMILY HYDRO UNITS. SUB-CONTRACTED FOR OTHER WORK.

TABLE 2: Capabilities of the main manufacturers of hydropower equipment in Vietnam

The Dong Anh Factory, owned by the Ministry of Energy, is also no longer manufacturing turbines. Between 1983 and 1988 it produced around 200 Francis, Kaplan, Banki and Propeller turbines and associated equipment in the range 5kW - 2MW. The efficiency of the turbines was often less than 70% and now many of them are not functioning.

The Hydro Electric Research Centre of the Institute of Hydraulic Research has produced 10 Francis turbines for schemes up to 200kW. The equipment appears to be of better quality and higher efficiency than other Vietnamese made equipment.

There currently appears to be no enthusiasm to buy from the manufacturers in Hanoi as Chinese turbines come in a wide range of products and are of a proven design [Cromwell & Pandey, 1991], and Vietnamese equipment has in the past been unreliable. Another reason why the two main companies which have made hydropower components in the past are no longer doing so is due to changes in government financing. In the past, funds were available direct from the government for individual projects. Now each province must supply its own funds which they are finding increasingly difficult to do. Thus hydropower equipment manufacture has become less profitable, and the return on investment is lower than for other products which the factories can produce. Also, for the first time, each of the factories has become accountable for its own financing as opposed to being government subsidised as was previously the case.

For schemes with capacities below 100kW, manufacturers only provide for manual governing, whereas for large capacities they produce a mechanical/hydraulic governor based upon a Chinese design [Interim Committee for Coordination of Investigations of the Lower Mekong Basin, 1988]. An electrical-hydraulic governor is presently being designed. At present the knowledge of ELC control is not wide-spread and no equipment is being manufactured in the country. There is a need for automatic control for the schemes below 100kW and ELC technology may be the way forward.

The use of generators reconditioned from old diesel sets has proved to be a cheap and reliable option.

In Vietnam the unreliability of locally manufactured equipment has adversely affected demand. With the low cost of reliable and efficient equipment which is now available, and a local repair facility, the demand for micro-hydro equipment is likely to rise again.

4. THE LAO PDR

4.1. Rural electrification

Lao PDR is considered to have one of the lowest consumption rates of electricity in the world [Pho Muangnalad, 1991], with less than 5% of the 4 million population having access to electricity. With an area larger than that of Great Britain (236,800 sq. km) it also has the lowest population density in South East Asia, and many of the villages are relatively remote, making the cost of extending local electrical grid lines extremely

high. Only 7.2% of villages were electrified by 1990 and from this, only 1.6% of the rural population had access to electricity [Sumphorn Manodham, 1992]. The prefecture of Vientiane accounted for approximately 85% of the electricity consumption in the country in 1986 [Government of Lao PDR, 1989].

Outside of the main towns there are some regional supplies, and many villages near to the main roads have a diesel generator which is often used for charging batteries. The supply of diesel is affected by the adverse weather conditions and the terrain, resulting in high fuel costs.

4.2. Mini-hydro and micro-hydro developments

Many villages have experience with harnessing hydro-power in the form of mechanical water-powered rice husking devices. Presently less than 20 micro-hydro sites (excluding family-hydro) have been built, though the terrain of the country, the high levels of rainfall and the dispersed population, make small-scale hydro developments a suitable choice for rural electrification. 80% of the country is covered by mountain and plateau regions and the average rainfall for the country is 1,800mm/year, whilst on the Boloven Plateau this rises to 3,600mm/year.

The majority of the existing schemes have been initiated by NGOs, and as such, their development has been erratic and piece-meal. Many of the micro-hydro plant are no longer operational, or are operating at low efficiency [Inversin]. Several schemes have been established by the Vietnamese within Lao PDR.

4.3. Local manufacture

Virtually all of the equipment presently available in the Lao PDR is imported, though several micro-hydro turbines have been manufactured in the Lao capital, Vientiane. Equipment has come from many countries including China, France, Germany, Japan, Nepal, Poland, Sweden, Thailand and Vietnam. Several workshops are capable of manufacturing turbines, penstock and some other mechanical components, and some workshops in the provinces are capable of making repairs to equipment. The organisation Techno Phatthana Khetphoudoi has designed and supervised the manufacture of two crossflow turbines in local workshops. The designs were based upon information obtained from a SKAT (Swiss Centre for Development Cooperation in Technology and Management) publication. Also the Department of Micro-hydropower of the Ministry of Agriculture and Forestry has commissioned the manufacture of a cross-flow turbine at their main workshop. This worked well for three years before siltation wear eroded the blade. The cost of the equipment was exceptionally low, but due to its failure, locally produced equipment has been seen by the government as being unreliable and uneconomic, particularly as many NGOs donate equipment.

Many of the generators used are from old diesel generator sets, as is the case in Vietnam. These are in abundant supply for a relatively low cost.

5. INTERNATIONAL COOPERATION AND TECHNOLOGY TRANSFER

It appears that many NGOs and other internationally organised projects are mainly concerned with setting up pilot projects. This has particularly been the case in the Lao PDR where projects, which have often been over-engineered, have provide a distorted view of the costs involved. Most do not help to build up the local manufacturing base and many ultimately undermine it by setting high engineering standards and encouraging funding organisations to buy foreign equipment. Single projects implemented by NGO's and government agencies seldom enhance the prospects of concerted nation-wide programmes, and they often do nothing to effectively increase the knowledge base in the country. Also economies of scale are never achieved. A clearly defined policy should be established so that governmental organisations and NGO's can be a part of this and contribute as usual within set guidelines. Also, without a coordinated approach, many different types of equipment will be used, leading to increased difficulty in the supply of spare parts, training and maintenance. If agencies were more willing to invest in a national initiative, though each agency may lose some control over their project, the overall national programme would be more effective.

There is a substantial market for both family-hydro equipment and crossflow turbines in the Lao PDR and there is a need for further technology transfer and support to be given to their manufacture. Table 3 summarises the manufacturing capabilities and recommendations for technology transfer for each of the three countries.

In Thailand the production of cheap family-hydro units could create a substantial market in Thailand. Those villages in hilly regions which are unlikely to receive electrification in the near future will be provided with an option for a basic supply. The equipment could either be manufactured in Thailand, or imported from Vietnam. Many Thai companies have the equipment to produce mini-hydro turbines, but this is unlikely to occur without effective transfer of the technology to those companies and an appreciation of the market for the equipment within the region.

	VIETNAM	THAILAND	LAO PDR
TURBINE MANUFACTURING CAPABILITIES	200W - 2.1MW	5 - 100kW	5 - 20kW
TECHNOLOGY TRANSFER REQUIREMENTS	ELC DESIGN. TURBINE BLADE IMPROVEMENTS	POSSIBLY FRANCIS TURBINE DEVELOPMENT. FAMILY HYDRO.	FAMILY HYDRO. CROSSFLOW DEVELOPMENT.

TABLE 3: Summary of manufactruing capabilities and recommendations for technology transfer

In Vietnam the technological knowledge for manufacturing small-scale hydropower equipment is adequate, but there is still a lack of certain know-how, such as detailed information concerning how to obtain more efficient blade profiles for Kaplan and Francis turbines, and also information about ELCs. This lack of information available to researchers, engineers and technicians in Vietnam is seen as being one of the greatest obstacles to the development of renewable energy technologies in the country [Nguyen Van Than, 1991]. They have become very skilled at copying foreign technology, especially as foreign capital is so scarce.

6. CONCLUSIONS

Technology was appropriated in each country by obtaining foreign equipment, or designs, and copying them. Equipment in Vietnam is cheap, though half of the sites built in the country are now not working. This has mainly been due to the lack of provision for financial security to pay for project repair and a lack of adequate maintenance. There are a large number of family-hydro sets being used and the relative low cost of these has established a large rural market.

The schemes established in Thailand have been more expensive, though better provisions have been made for maintenance and repair. The use of ELC has provided a relatively cheap and reliable form of governing. Family hydro could be imported from Vietnam to provide a basic supply to those villages which are not likely to receive electricity via government programmes.

In the Lao PDR, very few schemes are in operation, and they are in a good position to learn from the different approaches of their Thai and Vietnamese neighbours. At present there is a lack of infrastructure and funds. Some local manufacture of equipment has taken place, but as yet this has not firmly established itself.

Establishing networks for international cooperation and the exchange of information can often be the catalyst for local manufacture, and international organisations, including NGOs, could also play a large role in supporting this.

REFERENCES

ATA, *"Progress report - micro hydropower project Jan 86 - July 87"*, internal report, ATA, Bangkok, 1987.

Brown, Andy, *"Field notes"*, internal report of Thailand field visit, ITDG, Rugby, no date.

Chulapongs Chullakesa, *"Technology applicable to Thailand's small hydro development"*, SHP News, No.3, 1991.

Chulapongs Chullakesa, *"Rural electrification in Thailand"*, in Rural Electrification Guidebook for Asia and the Pacific, AIT, Bangkok, 1992.

Cromwell, Godfrey & Pandey, Bikash, *"Feasibility Study of Micro-hydro projects in Bac Thai Province, Vietnam"*, ITDG, Rugby, 1991.

Etienne, Jacques & Schadegg, Marcel, *"Ten years of experience of transfer of technology in Thailand"*, Fourth International Conference on Small Hydro, Water Power and Dam Construction, Kuala Lumpur, Oct 1990.

Government of Lao PDR, *"Report on the economic and social situation, development strategy and assistance needs of the Lao PDR"*, Vol 1, Prepared for the round table meeting in Geneva, Government of Lao PDR, Vientiane, April 1989.

Ha Tien Luy, *"Vietnam special: Small hydro power development in Vietnam"*, SHP News, No.3, 1989.

Helling, A. L., *"Technology adaption for development: Assessing Thailand's micro-hydro programme"*, Masters thesis, AIT, Bangkok, 1986.

Interim Committee for Coordination of Investigations of the Lower Mekong Basin, *"Standardization of micro-hydro components for Thailand, Lao PDR and Vietnam"*, Mekong Committee, Bangkok, 1988.

Inversin, A, *"Thoughts for a proposal for a micro-hydropower effort in Laos"*, unpublished report, NRECA, Washington DC, no date.

Nguyen Duc Loc, *"New and Renewable Sources of Energy Application in Vietnam"*, Asia Energy '91 Conference, Bangkok, 1991.

Nguyen Khac Diem, *"Small hydro development in Vietnam"*, in Conference papers of 5th International Conference on Small Hydro, International Water Power and Dam Construction, London 1992, pp120 - 128.

Nguyen Van Than, *"Country paper: energy policy for rural development of Vietnam"*, Asia Energy '91 Conference, Bangkok, 1991.

Pho Muangnalad, *"New and renewable energy in Lao PDR"*, presented at Asia Energy '91 Conference, Bangkok, 1991.

Saunier, G, *"Rural electrification guidebook"*, AIT, Bangkok 1992, pp455 - 469.

SHP News, No.2, 1989, p5.

Sumphorn Manodham, *"Rural electrification in Lao People's Democratic Republic",in "Rural electrification guidebook"*, AIT, Bangkok 1992.

UN, *"New and renewable sources of energy for development"*, Energy resources development series No.30, UN Publications, Bangkok, 1988.

UNCTAD Secretariat, *"Technology policy in the energy sector: issues, scope and options for developing countries"*, UN Publications, Geneva, 1990.