ICIMOD

Energy Use in Mountain Areas

Trends and Patterns in China, India, Nepal and Pakistan

Edited by
Kamal Rijal

International Centre for Integrated Mountain Development (ICIMOD)
Kathmandu, Nepal
February 1999

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Photo Credits : *Kamal Rijal*
Cover Photos : 1) Chinese type solar cooker, Lhasa, Tibet
2) Nepali women carrying fuelwood for cooking fuel

Published by
International Centre for Integrated Mountain Development
G.P.O. Box 3226
Kathmandu, Nepal

ISBN 92 9115 872 0

Layout by
Dharma R. Maharjan

Typesetting at
ICIMOD Publications' Unit

Foreword

A key characteristic of energy systems in mountain areas is that they remain heavily dependent on wood fuels; the supply of which is becoming critical as a result of the increasing rate of deforestation. Use of easily available alternative sources of energy can involve significant tradeoffs in agricultural productivity, as a result of the diversion of crop and animal wastes into cooking and heating devices. Furthermore, most energy forms are used inefficiently. The dependence on wood results in environmental consequences such as loss of forests and woodlands, in bad health associated with indoor air pollution, and in a range of adverse social and economic impacts arising from fuel collection and use, many of which fall disproportionately on women and children.

Matching supply of and demand for energy in mountain areas is probably more complex than anywhere else, both in terms of its problems and its opportunities. As fossil fuels are not easily available, or are much too expensive for daily use, mountain people have traditionally relied on biomass fuels for cooking and heating and on animal and human power for draught and transport. The role of energy in reducing drudgery in mountain areas, and in supporting and sustaining income-generating activities, is also being recognised increasingly. Energy is a prime mover in nearly all development endeavours; and the mountains are endowed with sources of hydropower and solar energy that for the most part remain untapped.

Given the trends, ICIMOD has concentrated on the key issue of energy in the mountains from its inception in 1984. The energy needs of mountain farming communities and of small urban centres in the mountains have been a priority. The state-of-the art reviews on rural energy carried out in the late 1980s in five countries of the Hindu Kush-Himalayan (HKH) region led to the conclusion that afforestation must receive priority as a means of overcoming the fuelwood crisis, and that programmes must be introduced to create energy options (small and micro-hydropower plants, biomass, biogas, and fossil fuel). A decentralised energy planning and management approach seemed to be a possible strategy. With these findings, a decentralised energy planning and management programme was introduced to develop methods of rural energy planning and management in the mountain regions; to disseminate them among district level officials; and to train trainers from selected institutions. Since this time, ICIMOD has shifted its focus to generating more knowledge about renewable energy technologies (RETs) and their suitability for use in mountain areas.

The knowledge generated, the lessons learned, the need for a shift in the energy development paradigm, and the fact that environmental sustainability has become of central importance in development thinking; all led to recognition of the need to promote appropriate policies and investment strategies for the development of a sustainable energy system in the HKH. The primary focus of ICIMOD's present activities related to energy is on understanding and documenting the dynamics of energy use in mountain areas and reviewing the state-of-the-art for renewable energy technologies such as those involving mini and micro-hydropower, biomass, and solar- and wind-based technologies.

As part of its energy programme, ICIMOD commissioned studies on energy use patterns in the HKH Region in four member countries in 1996; viz., in China, India, Nepal, and Pakistan. The main aims of the study were to improve understanding of the issues emerging in energy use patterns, policies, and programmes and to propose strategies for and approaches to sustainable energy development in the mountains.

The present publication contains summaries of the country review studies, together with an account of the main policy and institutional issues identified and a description of approaches and strategies proposed for sustainable energy development in the mountains. The information is presented in seven chapters.

Chapter 1 summarises and compares the present patterns in energy use and resource availability, factors influencing energy use patterns, and constraints to the development of the energy sector in the countries of the HKH Region as a whole, as these would have an influence on the development of the energy sector in the HKH Region of each country. Chapter 2 summarises the main findings of the studies carried out in four countries, covering the HKH Region of each country exclusively. This is a first attempt to analyse and present the energy use pattern, status of renewable energy technologies (RETs), energy policies, programmes and institutions within the HKH Region of these four countries.

Chapters 3, 4, 5, and 6 summarise the energy consumption patterns, energy resource base, energy use variability, status of renewable energy technologies, energy planning, and programme implementation in the HKH regions of each of the four countries separately. Each of these chapters also examines the environmental impact of energy use. These chapters provide a strategic framework and broad policy guidelines for the development of the energy sector in the HKH region of each country.

Chapter 7 summarises the energy issues in mountain areas. These are: prevailing unsustainability of energy supply and demand; inharmonious energy transitions, on the one hand towards non-monetised, low quality energy forms, and on the other towards non-renewable fossil fuels; wrong choice of energy resources and technologies as a result of lack of a perspective for quality and quantity and lack of community participation in energy programme design; lack of a long-term vision for the development of energy in the mountains; ignorance of the bio-physical aspects of mountain areas; lack of recognition of the importance of gender and sociocultural issues; lack of institutional, financing, and investment policies; insufficient focus on research and development of new energy systems suitable for the mountains; and the methodological dilemma of having to internalise environmental costs. The chapter also discusses an approach towards sustainable energy development which examines the specific characteristics of the mountain situation and their implications for the energy sector and the suitability of energy resources in the mountains. Finally, the chapter proposes various components of an energy development strategy for the mountains. It also provides broad guidance for designing and implementing energy programmes for mountain communities.

The publication finishes with two annexes. Annex A contains a set of methodological guidelines for preparing an energy database. These guidelines will be instrumental for carrying out area-based energy planning and for programme implementation. Annex B contains energy balance tables for all the mountain areas investigated. This set of tables is the first of its kind for this region.

We believe that this publication will be of use to energy planners and development specialists in national institutions, as well as to NGOs and donor agencies engaged in the development of mountain areas and committed towards meeting the energy needs of mountain communities.

I would like to extend my sincere appreciation to the study team from China, comprising of Mr. Wang Mengjie, Mr. Wang Gehua, Mr. Xiao Mingsong, and Mr. Ding Yi from the Chinese Academy of Agricultural Engineering, Research and Planning (CAAERP), Beijing; to Prof. N. K. Bansal of the Centre for Energy Studies, Indian Institute of Technology (IIT), New Delhi, India; to Dr. Kamal Banskota and Mr. Bikash Sharma of the Centre for Resource and Environmental Studies (CREST), Kathmandu, Nepal; and to Prof. M. Abdullah of the University of Engineering and Technology, Peshawar, Pakistan, for carrying out the energy use pattern studies in the HKH regions of their respective countries. This study is the first of its kind and has succeeded in capturing the trends and patterns of energy use in the HKH Region, besides putting forth ideas for the sustainable development of energy in the context of mountain areas. The document was reviewed externally by Dr. P. Venkata Ramana, Dean, Tata Energy Research Institute (TERI), New Delhi, India, and ICIMOD is thankful for his valuable comments which helped improve the quality of this publication.

Finally, I would like to thank Dr. Kamal Rijal, Energy Specialist, ICIMOD, who, as the coordinator of the programme, has been responsible for bringing out this document in its present form.

Egbert Pelinck
Director General

Abstract

This publication summarises the main findings of a set of studies on energy use patterns in the HKH region carried out in four countries separately, namely, China, India, Nepal, and Pakistan. The results of the studies were used to prepare energy balance tables for the HKH Region of each country and to identify issues emerging concerning energy use. The issues identified were: prevailing unsustainable trends in energy supply and demand in the mountains; inharmonious energy transitions, on the one hand towards non-monetised, low quality energy forms and on the other towards non-renewable fossil fuels; wrong choice of energy resources and technologies as a result of a lack of perspective related to both quality and quantity of energy in programme design; ignorance of the bio-physical aspects of mountain areas; weak gender participation; lack of understanding of sociocultural issues; lack of a suitable institutional framework to promote decentralised renewable energy technologies; and the methodological dilemma of internalising environmental concerns.

The publication also proposes a four-pronged strategy for sustainable energy development in the mountains. First, programmes must be geared towards increasing wood resources on a large scale and to upgrading the quality of biomass fuels in order to meet cooking and heating needs. Second, energy policies for mountain areas should emphasise new and renewable decentralised resources and technologies (via rural electrification or motive power generation), not only in order to sustain and increase economic activities but also to reduce human drudgery, particularly that of women and children. Third, efficient energy technologies should be promoted to facilitate improvements in the physical quality of life and achieve a significant reduction in health hazards. Fourth, large-scale development of hydropower should be initiated, in order to generate revenue for alleviating the existing poverty of mountain communities and to develop social and physical infrastructures suitable for these communities. At the same time, care must be taken not only to internalise the associated environmental costs into these projects, but also to ensure that such development results in the overall development of mountain areas.

The publication also describes the various policy and institutional measures that need to be taken so that sustainable development of the energy sector in the HKH Region can become a feasible proposition. These measures are: a) removal of the existing distortion in prices; b) encouragement of entrepreneurs; c) promotion of technology transfer and more efficient fuel use; c) dissemination of information on suitable technological options; d) enforcement of regulations, standards, and codes for the promotion of economic and allocative efficiency; e) performance of R&D to develop low-cost and efficient mountain region-specific renewable energy technologies; f) encouraging the development of participatory institutions; g) ensuring the participation of, and a greater decision-making role for, women in energy programmes; and h) initiating various programmes for building capabilities at the local level.

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Abbreviations

ADB	Asian Development Bank
ADB/N	Agricultural Development Bank, Nepal
AJK	Azad Jammu and Kashmir
AKHBP	Aga Khan Housing Board of Pakistan
AKRSP	Aga Khan Rural Support Programme (Pakistan)
APDC	Asia and Pacific Development Centre
APEDA	Arunachal Pradesh Energy Development Agency
ATDO	Appropriate Technology Development Organization (Pakistan)
ATF	Aviation Turbine Fuel
BEW	Butwal Engineering Works
BYS	Balaju Yantra Shala
CAAERP	Chinese Academy for Agricultural Engineering Research and Planning
CB	Cost benefit (ratio)
CMIE	Centre for Monitoring the Indian Economy
CRE	Centre for Renewable Energy
CRET	Council for Renewable Energy Technologies (Pakistan)
CREST	Centre for Resource and Environmental Studies
CRT	Centre for Rural Technology
DA	Development Alternatives
DANIDA	Danish International Development Agency
DeLF	Development Law Forum
DGNRER	Director General Office of New and Renewable Energy Resources (Pakistan)
dLA	deLucia and Associates Inc.
DMD	Directorate of Mineral Department (Pakistan)
DPR	Detailed Project Report (India)
EDA	energy demand analysis
EIA	environmental impact assessment
ESCAP	Economic and Social Commission for Asia and the Pacific
FAC	fuel adjustment charge
FAO	Food and Agriculture Organization (UN)
FATA	Federally Administered Tribal Areas
FECT	Fuel Efficient Cooking Technology (Pakistan)
FINNIDA	Finland International Development Agency
FSI	Forestry Survey of India
FSMP	Forestry Sector Master Plan (Pakistan)
FY	Fiscal year
GDP	gross domestic product
GEF	Global Environment Fund
GGC	Gobar Gas Company
GHG	greenhouse gases
GIDS	Giri Institute of Development Studies
GJ	gigajoule
GNP	gross national product
GOI	Government of India
GOP	Government of Pakistan
GTZ	German Agency for Technical Cooperation
GWh	gigawatt hour
ha	hectare
HDI	human development indicator
HESCO	Himalayan Environment and Science Conservation Organization
HESS	Household Energy Strategy Study (Pakistan)
HIMURJA	Himachal Pradesh Energy Development Agency
HKH	Hindu Kush-Himalayas

HMG/N	His Majesty's Government of Nepal
HP (hp)	horsepower
HSDO	high speed diesel oil
H.S.U	Hortridge smoke unit
ICIMOD	International Centre for Integrated Mountain Development
ICS	improved cooking stove
IDA	international development aid
IGF	Inspector General of Forests (Pakistan)
IIT	Indian Institute of Technology
INPS	Interconnected Nepal Power System
IR	industrialisation ratio
IRs	Indian Rupees
IREDA	Indian Renewable Energy Development Agency
IREP	Integrated Rural Energy Programme (India)
IUCN	International Union for the Conservation of Nature
J&K	Jammu and Kashmir
JICA	Japan's International Cooperation Agency
KESC	Karachi Electricity Supply Corporation
KMTNC	King Mahendra Trust for Nature Conservation
kW	kilowatt
kWp	kilowatt peak
kWh	kilowatt hour
KVIC	Khadi and Village Industries' Commission (India)
LOD	light diesel oil
LPG	liquefied petroleum gas
LRMP	Land Resource Mapping Project
masl	metres above sea level
MEI	mountain enterprise and infrastructure
MHP	micro-hydropower
MJ	Mega Joule
MMHP	mini- and micro-hydropower
MNES	Ministry of Non-Conventional Energy Sources
MOA	Ministry of Agriculture (China)
MOE	Ministry of Energy (China)
MOES	Ministry of Environmental Science (China)
MOF	Ministry of Finance
MOF	Ministry of Forests (N.B., In the Chinese Section this acronym has the meaning given here.)
MOMG	Ministry of Mines and Geology (China)
MOST	Ministry of Science and Technology (Pakistan; China)
MOU	Memorandum of Understanding
MPFS	Master Plan for the Forestry Sector (Nepal)
MPPU	multi-purpose power unit
MS	motor spirit
MW	megawatt
NA	Northern Area
n.a.	not available
NBSM	Nepal Bureau of Standards and Metrology
NCI	Non-Cultivable Inclusion
NCL	Nepal Coal Limited
NCS	National Conservation Strategy (Pakistan)
NEA	Nepal Electricity Authority
NEC	North East Council
NEPC	National Environmental Protection Council (Nepal)
NGO	non-governmental organization
NHEC	Nepal Hydro and Electric Companies Pvt. Ltd.
NIST	National Institute for Silicon Technology (Pakistan)
NOC	Nepal Oil Corporation
NPC	National Planning Commission (Nepal)

NPBD	National Project on Biogas Development (India)
NRIs	non-resident Indians
NRs	Nepali Rupees
NRSE	New and renewable sources of energy
NWFP	North West Frontier Province
ONGC	Oil and Natural Gas Corporation (India)
PCAT	Pakistan Council for Appropriate Technology
PCSIR	Pakistan Council for Scientific and Industrial Research
PDD	Planning and Development Department (Pakistan)
PEP	Perspective Energy Plan
PEYB	Pakistan Energy Year Book
PGOB	Provincial Government of Balochistan
PMC	project management cell
PMDC	Pakistan Mineral Development Corporation
PNCS	Pakistan National Conservation Strategy
PRs	Pakistani Rupees
PV	photovoltaic
R&D	research and development
RECAST	Research Centre for Applied Science and Technology
RES	reference energy system
RET(s)	renewable energy technology
RMB	Before Yuan
RONAST	Royal Nepal Academy for Science and Technology
ROR	rate of return
R-O-R	run of the river
SBC	Statistics Bureau of China
SBS	Statistics Bureau of Sichuan
SBX	Statistics Bureau of (Tibetan) Xizang Autonomous Region
SBY	Statistics Bureau of Yunnan
SCOPE	Society for Constitutional and Parliamentary Exercise
SEB	State Electricity Board (India)
SHYDO	Small Hydel Development Organization/Sarhad Hydel Development Organization (Pakistan)
SKO	kerosene
SNV-Nepal	Netherland's Development Organization, Nepal Office
SPV	solar photovoltaic
SPCS	Sarhad Provincial Conservation Strategy (Pakistan)
SSGC	Southern Sui Gas Company Limited (Pakistan)
TCN	Timber Corporation of Nepal
TDAP	Technology Development Action Plan (Pakistan)
TERI	Tata Energy Research Insitute
TSP	total suspended particles
UHV	useful heating value
UMN	United Mission to Nepal
UN	United Nations
UNCDF	United Nations Capital Development Fund
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Organization for Education, Science, and Culture
UNICEF	United Nations International Children's Fund
UR	urbanisation ratio
US/USA	United States (of America)
USAID	United States Agency for International Development
WAPDA	Water and Power Development Authority (Pakistan)
WB	World Bank
WECS	Water and Energy Commission Secretariat
WGEP	Working Group on Energy Policy
WRI	World Resources' Institute

Definitions and Explanations

Currency Exchange Rates (FY 1994/5 - as of December 1994)

China	:	1 US Dollar	= 8.30 RMB
India	:	1 US Dollar	= 31.94 IRs.
Nepal	:	1 US Dollar	= 49.00 NRs.
Netherlands	:	1 US Dollar	= 1.74 Dutch Guilders
Pakistan	:	1 US Dollar	= 30.60 PRs.

Fiscal Year

China	:	Starting 1 January to 31 December
India	:	Starting 1 April to 31 March
Nepal	:	Starting 15 July to 14 July
Pakistan	:	Starting 1 July to 30 June

Micro-, Mini- and Small Hydropower Definitions and Classification

Name of the Country/ Organization	Micro kW	Mini kW	Small MW
China	100	>100- 500	25
India	100	>100-3000	>3 - 15
Nepal	100	>100-1000	>1 - 15
Pakistan	100	>100-1000	>1 - 10
USA	500	>500-2000	>2 - 15
UNIDO	100	>100-1000	>1 - 10

Units

one crore	=	10 million
one billion	=	1,000 million
one trillion	=	1,000 billion

Chapter 1

Background of the Countries of the HKH Region[1]

by
Kamal Rijal

1.1 Introduction

The eight countries of the Hindu Kush-Himalayan region[1] (Figure 1.1) have a total population of 2,456 million; 130 million or more than five per cent of them live in the HKH itself. The average population density in these countries overall is 160 persons per square kilometre, and in the HKH region alone 38 persons per square kilometre (Rijal 1996). The percentage of the total populations of the four countries studied in detail that live in the HKH region are 19.7 million for China, 31 million for India, 100 per cent for Nepal, and 24.2 million for Pakistan. In the case of Nepal, the Terai region (17% of the total area of Nepal) is also included within the HKH. There is a substantial variation in the population density in the HKH region between countries, from 133 persons per square kilometre in Nepal to 12 persons per square kilometre in China. Table 1.1 summarises some selected socioeconomic indicators in the countries of the region and Figure 1.2 compares the human development indicators (HDI) in these countries. Though the HDI Index for the HKH per se is not available, the low level of literacy and high percentage of poverty prevalent in the region reflect the poor quality of life of the majority of the population. These

[1] The 3,500km mountain range that stretches from Afghanistan in the west through Pakistan, India, China, Nepal, Bhutan, and Bangladesh to Myanmar in the east is home to more than 130 million people.

Figure 1.1 : The Hindu Kush-Himalayan Region

Table 1.1: Socioeconomic Parameters of Countries of the HKH Region, Fiscal Year (FY) 1994

	Units	Afghanistan	Bhutan	Bangladesh	China	India	Myanmar	Nepal	Pakistan	Total/ Average
Population	Millions	17.4	0.6	117.7	1208.8	918.6	45.6	19.7	126.6	2456.0
Area	000 sq.km.	652.1	46.5	144.0	9607.0	3287.3	676.3	147.2	796.1	15356.7
Population Density	Per sq.km.	27	13	817	126	279	67	134	159	160
GDP per Capita	US$	125	470	220	557	321	219	203	408	431
- Agriculture	%	53	40	30	27	27	47	42	22	27
- Manufacture/Industry	%	29	31	18	47	28	20	27	32	37
- Other	%	19	29	52	26	45	33	32	46	36
Real GDP per Capita	PPP		1289	1331	2604	1348	1051	1137	2154	1990
Life Expectancy[1]	Yrs.		66	56	69	61	58	55	62	64
Fertility Rate	Nos.		6	4	2	4	4	6	6	3
Infant Mortality Rate	Per 1000		71	77	26	84	48	91	95	54
Adult Illiteracy	%		55	63	19	49	17	73	63	35
- Adult Female Illiteracy	%		75	76	29	64	23	87	77	47
Urbanisation Ratio	%		6	18	29	27	26	13	34	28
Industrialisation Ratio	%	29	37	18	47	28	20	27	32	37
HDI Index			0.338	0.368	0.626	0.446	0.475	0.347	0.445	
GDP Index			0.2	0.2	0.41	0.21	0.16	0.17	0.34	
Education Index			0.38	0.38	0.73	0.53	0.71	0.36	0.37	
People in Abs. Poverty[1]	%	59	0	79	9	38	34	63	28	25
People with Access to										
- Health Services (1990-95)	%		65	45	88	85	50	n.a.	55	81
- Safe Water (1990-96)	%		58	97	67	81	60	63	74	73

Yrs. = years; Nos. = numbers; GDP = gross domestic product; Abs. = absolute; PPP = Purchasing Power Parity

Note: [1] Data are for 1992.

Sources:
1. Statistical Year Book for Asia and the Pacific - 1995, ESCAP, UN 1996
2. Human Development Report, UNDP 1997
3. Data for Bhutan provided by the Ministry of Agriculture of the Royal Government of Bhutan.

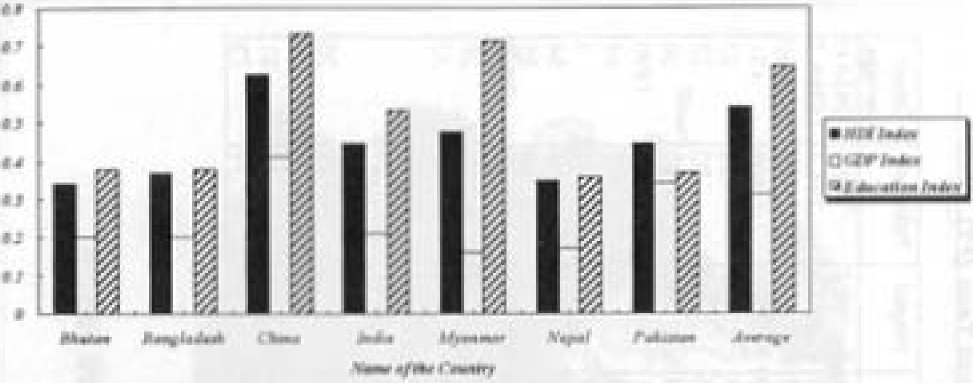

Figure 1.2: Human Development Indicators in the Countries of the HKH Region

figures are those for the whole of each country, there are no separate HDI figures available for the HKH region. However, various indicators show the HKH regions in the respective countries to be worse off than the rest of the country, and it seems likely that the HDIs for the HKH regions will be much lower than the country averages shown. The low level of literacy and high percentage of poverty prevalent in the region reflect the poor quality of life of the majority of the population.

A large majority of the population of the countries within which the HKH region is located remains without access to safe water or adequate health facilities. Poverty levels are high and, according to the UNDP Report on Human Development (1997), 625 million of the total 1175 million people living in absolute poverty in the world live in the HKH countries (more than 25% of their population), most of them within the HKH region itself. The infant mortality rate in the countries of the HKH region varies from 26 to 95 per 1,000 births compared with a global infant mortality rate of 58 (UNDP 1997). Even though economic growth and development has improved living standards, the HKH region remains one of the poorest in the world.

1.2 Current Energy Situation

1.2.1 Energy Resource Base

The energy resource base of the countries of the HKH region consists of a combination of traditional and commercial sources such as fuelwood, agricultural residues, animal waste, hydroelectricity, petroleum fuels, coal, and wind and solar power. The energy potentials in the countries of the region are shown in Table 1.2. The present sustainable supply of energy per capita amounts to about four times the total energy consumption, and 27 per cent of the total is in the form of renewable

Table 1.2: Energy Resource Base in the Countries of the HKH Region

Energy Forms	Unit	Afghanis-tan	Bhutan	Bangla-desh	China	India	Myan-mar	Nepal	Pakistan	Total
Coal	000 MT	112000		1054000	286400000	131254000	5000		28590	418853590
Oil	000 MT			4983	3264000	810000	7000		28826	4114809
Natural Gas	Mil. m3	100000		360000	1127000	730000	265000	5	728000	3310005
Uranium	MW					10000			10000	20000
Peat	000 MT			138000	4687000	10571167			0	15396167
Geothermal	MWh									0
Hydro	MW		20000	1400	335000	150000	20000	83000	30000	639400
Wind	MW					20823		15	2642	23480
Wave	MWh									0
Biomass	000 MT	15882	1382	34563	767726	760845	16011	13323	22729	1632461
Solar	MW	130400	9400	28800	1912200	657600	127953	26649	159200	052202
Coal	Mil. GJ	2822	0	26561	7217280	3307601	126	0	720	10555110
Oil	Mil. GJ	0	0	229	150144	37260	322	0	1326	189281
Natural Gas	Mil. GJ	3600	0	12960	40572	26280	9540	0	26208	119160
Uranium	Mil. GJ	0	0	0	0	158	0	0		315
Peat	Mil. GJ	0	0	2484	84366	190281	0	0	0	277131
Geothermal	Mil. GJ	0	0	0	0	0	0	0	0	0
Hydro	Mil. GJ	0	315	22	5282	2365	315	1309	473	10082
Wind	Mil. GJ	0	0	0	0	328	0	0	42	370
Wave	Mil. GJ	0	0	0	0	0	0	0	0	0
Biomass	Mil. GJ	233	20	506	11247	11146	235	195	333	23916
Average Insolation	Mil. GJ	2056	148	454	30152	10369	2018	420	2510	48127
Total	Mil. GJ	8711	484	43217	7539043	3585788	12555	1925	31770	11223493
		0%	0%	0%	67%	32%	0%	0%	0%	100%
Renewable	Mil. GJ	2289	484	983	46681	24209	2567	1924	3358	
		3%	1%	1%	57%	29%	3%	2%	4%	100%
Non-renewable	Mil. GJ	6422	0	42234	7492362	3561579	9988	0	28412	11140998
		0%	0%	0%	67%	32%	0%	0%	0%	100%
Yearly Supply Potential	MJ/capita	139319	285907	15698	162888	104364	60926	99276	39344	125093
Renewable		131946	285907	8522	38925	26818	56543	99276	34856	34370
Non-renewable *		7374	0	7177	123964	77546	4384	0	4488	90723

MT = metric tonnes; mil. = million;

Note : * non-renewables defined as sources that will be consumed within 50 years

Source : Rijal 1996

sources. A large variation is observed between the different countries in the region, however. For example, renewable energy represents more than 90 per cent of the total potential supply in Afghanistan, Bhutan, Myanmar, Nepal, and Pakistan, more than seven times the present annual level of consumption of total energy per capita, whereas it represents less than 25 per cent of the total potential supply in China and India. The potential supply of non-renewable fuels exceeds the current level of energy consumption in countries like China and India and could supplement renewable sources to some extent in countries like Bangladesh, Myanmar, and Pakistan.

The resources available in different countries in the region vary significantly. For example, almost all of the coal is available in China and India. The potential for renewable energy per capita accounts for 16 per cent of the total energy potential in China and 26 per cent in India. The sustainable supply of renewable energy represents more than 90 per cent of the total potential energy supply in Afghanistan, Myanmar and Pakistan, and 100 per cent of that in Bhutan and Nepal.

The primary energy production in the countries of the HKH region is shown in Table 1.3. There is a huge difference between the supply potential of energy resources and their present annual level of production. This has created a situation in which countries are having to import commercial fuels even though they have a surplus of energy in terms of resource availability. This results from the fact that the capital investment required for the exploitation of the potential resources is quite high and mostly beyond the investment capability of these countries. At the same time, the technology options available at present are either costly or not reliable and deter countries from taking the financial risk associated with exploitation of their resources, even though the population has a pressing need. The best approach to solving this dilemma might be to use small-scale investment to extract the available energy resources and to develop decentralised and reliable technologies, with the objective of gradually building up human resources and financial capability.

2.2.2 Energy Consumption Pattern

The total final energy consumption in the countries of the region in FY 1994/5 amounted to 78,806 million GJ. On average 67 per cent of total consumption was met by commercial energy forms and the rest by biomass fuels, but there is a wide variation between the different countries in the share of traditional fuels. China and India consume about 66 per cent and 28 per cent of the total energy, respectively, while the remaining countries consume less than six per cent of the total. The share of biomass fuels in countries such as Afghanistan, Bhutan, Nepal, and Myanmar lies between 70 per cent and 95 per cent, while in China it is less than 25 per cent (Table 1.4).

Table 1.3: Primary Energy Production in the Countries of the HKH Region, 1994

Energy Forms	Unit	Afghanis-tan	Bhutan	Bangla-desh	China	India	Myanmar	Nepal	Pakistan	Total
Hard Coal	'000 MT	6	2	0	1239902	254658	36	0	3534	1498138
Coke	'000 MT	0	0	0	97807	10836	0	0	764	109407
Lignite	'000 MT	0	0	0	0	19201	40	0	0	19241
LPG	'000 MT	0	0	9	4445	2744	11	0	79	7288
Motor Gasolene	'000 MT	0	0	105	28541	4097	192	0	998	33933
Kerosene	'000 MT	0	0	420	4072	5206	1	0	488	10187
Jet Fuel	'000 MT	0	0	5	0	1992	52	0	467	2516
Diesel	'000 MT	0	0	255	34795	19676	405	0	1761	56892
Fuel Oil	'000 MT	0	0	310	30490	9860	96	0	1878	42634
Natural Gas	TJ	6830	0	232658	684435	664257	53026	0	580128	2221334
Electricity Production	Mil. kWh	687	1682	10010	928083	384422	3500	941	57147	1386472
- Thermal	Mil. kWh	215	7	9410	745927	307700	1917	33	37214	1102423
- Hydro	Mil. kWh	472	1675	600	168113	71065	1583	908	19436	263852
- Nuclear	Mil. kWh				14043	5600			497	20140
- Geothermal						57				57
Electricity Import	Mil. kWh	128	3		1847	1600		95		3673
Electricity Export	Mil. KWh		1445		3893	120		63		5521
Final Commercial Energy Production										
Petroleum Products	000 GJ	0	0	51167	4758694	2011908	34844	0	260414	7117028
Natural Gas	000 GJ	6830	0	232658	684435	664257	53026	0	580128	2221334
Coal and Coke	000 GJ	151	50	0	34179740	7088080	1627	0	111977	41381626
Electricity - Renewables	000 GJ	1699	6030	2160	655762	276199	5699	3269	71759	1022576
Total Commercial Energy	000 GJ	8680	6080	285985	40278631	10040444	95196	3269	1024278	51742564
Net Comm. Energy Import	000 GJ	13066	-3287	46204	47747	882716	7967	18796	388258	1401466
Import Dependency	%	60	-118	14	0	8	8	85	27	3
Biomass Production										
Forest Area	000 sq.km.	19.0	31	19	1305	685	324	58	35	2475
	% of total	2.9	67	13	14	21	48	39	4	16
Annual Deforestation [1]	%		0.6	3.3	0.9	0.6	1.2	1.0	2.9	0.9
Fuelwood Production	'000 MT	5617	1270	5900	204059	269187	20040	17985	25656	549714
Agric. & Animal Residue	'000 MT	562	64	29033	339820	376303	360	775	10784	757698

LPG = liquified petroleum gas; comm. = commercial; agric. = agricultural; MT = metric tonnes; mil. = million;

Note: [1] Data are for 1992

Sources: UN 1996; TERI 1997: WRI/UNEP/UNDP/WB 1996; WB 1997

Prepared by: K. Rijal

Table 1.4: Per Capita Final Energy Consumption Pattern in the Countries of the HKH Region

	Afghanis-tan	Bhutan	Bangla-desh	China	India	Myanmar	Nepal	Pakistan	Average
In MJ/capita									
Biomass	15,366	14064	4,051	9,649	12,625	6,100	11,641	11,197	10,458
Petroleum Fuels	724	858	785	4,258	2,857	932	810	4,906	3,479
Natural Gas	392	0	1,977	566,723	1,164	0	4,582	902	
Coal	9	298	42	28,000	8,005	43	139	1,102	16,836
Electricity	124	496	18	536	306	125	137	567	412
Total Commercial Fuels	1,248	1,653	2,822	33,361	11,891	2,264	1,086	11,197	21,485
Total Energy	16,614	15,717	6,873	43,010	24,517	8,364	12,727	22,353	32,087
Percentage of total									
Biomass	92	90	59	22	52	73	92	50	33
Petroleum Fuels	4	5	11	10	12	11	6	22	11
Natural Gas	2	0	29	1	3	14	0	21	3
Coal	<1	2	<1	65	33	<1	1	5	52
Electricity	<1	3	<1	1	1	1	1	2	1
Total Commercial Fuels	8	10	41	78	48	27	8	50	67
Total Energy	100	100	100	100	100	100	100	100	100

Sources: Rijal 1996; Abdullah 1997; Banskota and Sharma 1997; UN 1996; WRI/UNEP/UNDP/WB 1996; TERI 1997; WB 1997

There is also a wide variation in the per capita final energy consumption pattern in the different countries. For example, per capita consumption in China is 6 times that in Bangladesh. This is the result of a combination of various socioeconomic factors and the availability of energy resources and reliable technologies.

The annual per capita electricity production (Figure 1.3) varies significantly in the region from 41kWh in Nepal to 768kWh in China, compared with 11,868kWh in the USA. Figure 1.4 shows the overall per capita electricity consumption in the countries of the HKH region together with the per capita consumption in the HKH area of each country. This figure illustrates the low electricity supply infrastructure within the HKH region. The overall commercial energy intensities in the countries of the HKH region are shown in Figure 1.5. Again the variation is considerable, from 60 MJ and 37 MJ per unit of GDP in US Dollars in China and India respectively, to six MJ in Nepal.

1.3 Factors Influencing Energy Use

Knowledge of socioeconomic factors is crucial for understanding the energy use pattern in the region, and such factors must be taken into account when developing strategies for the sustainable development of energy. Some of the most important factors that affect the energy use pattern in the region are described in the following passages. Clearly, though, there are many other factors that could influence energy use significantly.

1.3.1 Population Dynamics and Urbanisation

The limited potential for improving the quality of life in rural areas forces people to migrate to urban centres. The sources and the demand patterns for energy vary markedly between rural and urban areas. These patterns are shown for Nepal as an example in Table 1.5. The transition from low-grade to high-grade energy in urban areas is instrumental in improving the energy utilisation efficiency. The result is a decrease in the absolute value of final energy consumption (by almost 44%, see Table 1.5).

In almost all urban areas in the region, increasing dependence on non-renewable energy is making the consumption pattern unsustainable in the long run. There is a crucial need to change the present supply mix dominated by imported fossil fuels to a more desirable supply mix with a high share of renewable energy.

Figure 1.6 shows the final commercial energy consumption in the countries of the region in relation to the ratio of urbanisation. It is clear that on average an increase in the urbanisation ratio will lead to an increase in the per capita consumption of

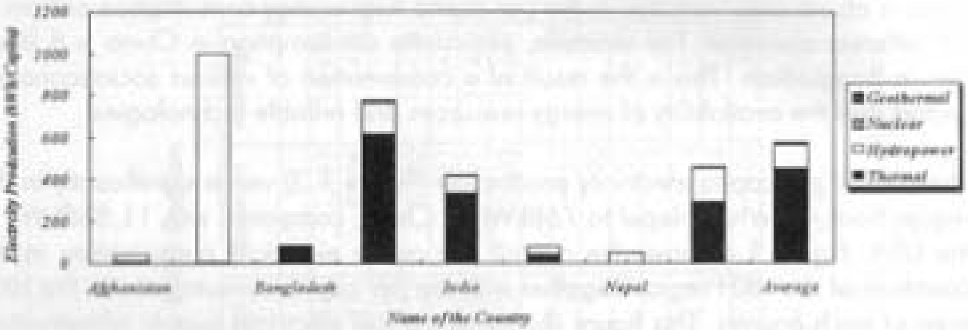

Figure 1.3: Per Capita Eelectricity Production in the Countries of the HKH Region

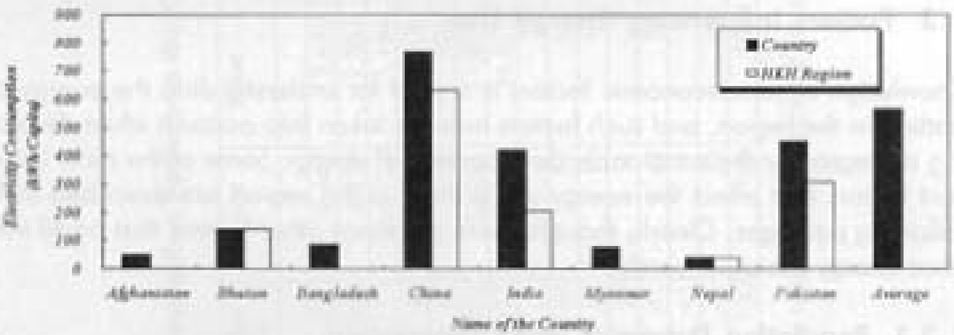

Figure 1.4: Per Capita Electricity Consumption within Countries and the HKH Region

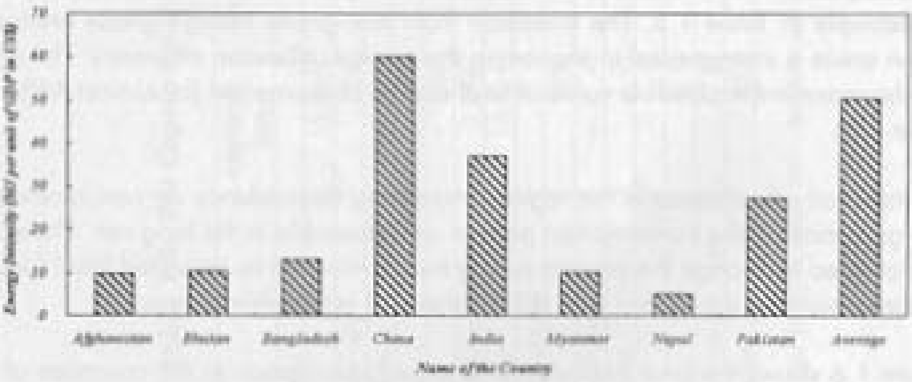

Figure 1.5: Commercial Energy Intensity in the Countries of the HKH Region

Table 1.5: Final Energy Consumption Pattern in the Rural and Urban Residential Sectors in Nepal

Type of Fuel	Rural Areas		Urban Areas	
	MJ/capita	Per cent	MJ/capita	Per cent
Biomass Fuels	11,930	99	5,693	84
Total Commercial	179	1	1,081	16
- Kerosene	164	<1	559	8
- LPG	0		142	2
- Electricity	14	<1	378	6
Total Energy	12,109	100	6,774	100

LPG = liquified petroleum gas

Source: WECS 1995

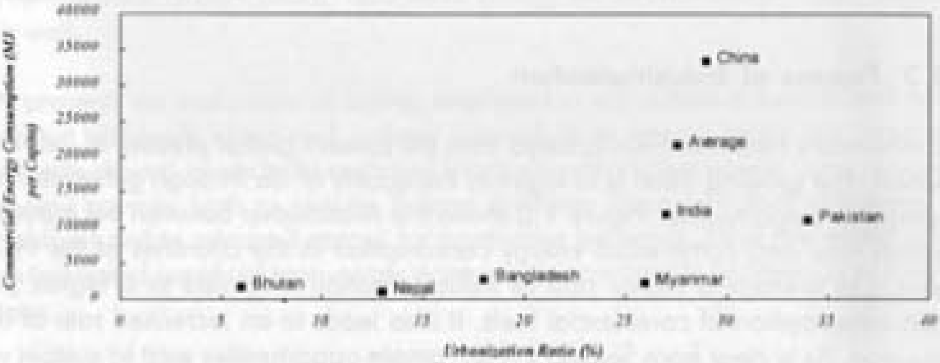

Figure 1.6: Relationship between the Urbanisation Ratio and Commercial Energy in the Countries of the HKH Region

commercial energy, whereas the consumption of biomass fuels decreases in urban areas due to increase in the efficiency of biomass fuel use.

1.3.2 Income and Energy Transition

Figure 1.7 shows the per capita commercial energy consumption in relation to the GDP per capita in the different countries of the region. Overall the energy consumption increases with GDP, though the trend is not uniform. The low income groups in the region tend to depend more on fuelwood, and when this is not available they are inclined to switch to other non-commercial energy forms. The high income households show a tendency to move up the energy ladder (to more use of kerosene, LPG [liquified petroleum gas], and/or electricity). The choice of energy resources and technologies clearly depends on the income available to the household. As people move out of a subsistence economy, they tend to use more efficient energy technologies and higher grade energy sources.

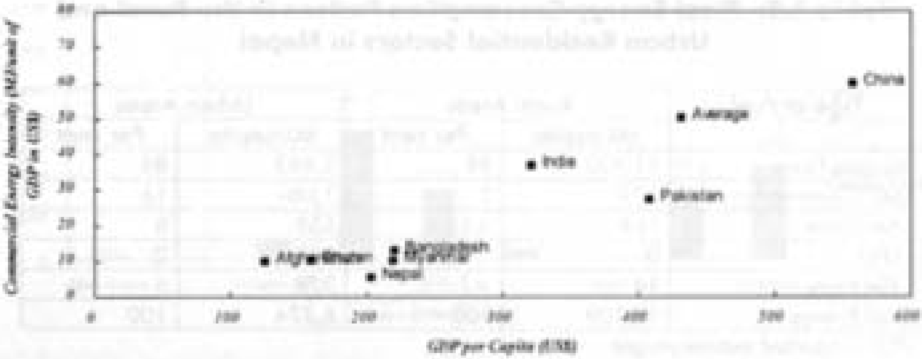

Figure 1.7: Relationship between GDP and Commercial Intensity in the Countries of the HKH Region

1.3.3 Process of Industrialisation

The mountains cannot remain isolated from the present global process of industrialisation. The growing trend is to improve the quality of life through generation of employment opportunities. Figure 1.8 shows the relationship between the industrialisation ratio and commercial energy consumption in the countries of the HKH region. On average a higher rate of industrialisation is related to a higher per capita consumption of commercial fuels. It also leads to an increased rate of urbanisation. As is clear from Section 1.1.2, ample opportunities exist to sustain an increasing rate of urbanisation and industrialisation in the region by maximising the use of indigenous renewable energy sources.

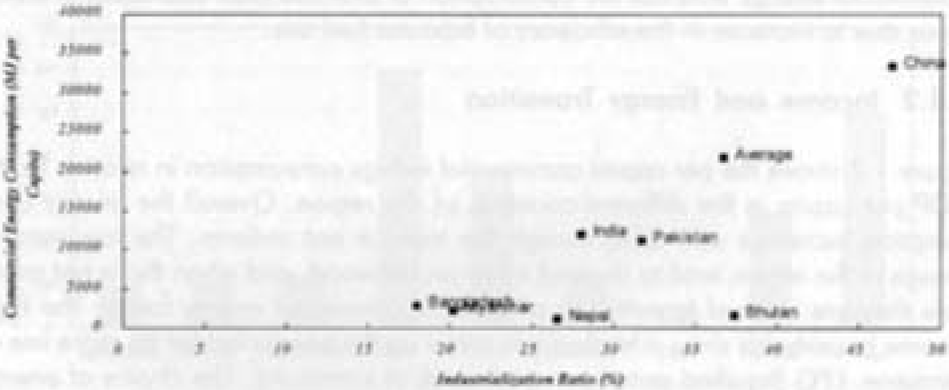

Figure 1.8: Relationship between Indus..ialisation Ratio and Commercial Energy in the Countries of the HKH Region

Various studies indicate a need to re-orient the development paradigm in relation to urbanisation and industrialisation in the context of the HKH region (Sharma and Banskota 1992). The nature and forms of industrialisation and urbanisation will have a significant impact on the demand pattern of energy. Any development approach that does not take into account the specific situation in the mountains when considering the provision of energy is bound to face severe problems in relation to the supply of energy and technology and is also likely to have a negative environmental impact. The paradigm will not suffer the constraints, only its application.

1.3.4 Diversification and Intensification of Agriculture

The concerted efforts of governments and donor agencies to eliminate poverty and improve the quality of life in mountain areas is likely to entail diversification and intensification of agriculture. Thus more energy will be needed to sustain this sector as well.

At present, the main form of energy employed in agriculture is human and animal labour, although direct and indirect uses of other energy forms are increasing. 'Muscle power' needs to be replaced gradually with motive power, using renewable energy sources both to reduce human drudgery (especially that of women and children) and to release livestock for productive purposes. All of this would require an increased supply of high-grade energy with appropriate technological interventions.

1.3.5 Human Development Indicators

There is no HDI Index available for the HKH region as such, but overall values are available for the different countries of the region (Table 1.1). In general the levels of development in the mountain areas are lower than those in other parts of these same countries, which in themselves are quite low compared to those in developed countries. Thus the HDI Indices for the HKH areas of each country are likely to be lower than those shown for each country as a whole (Fig 1.9).

There is a strong correlation between HDI, education index, infant mortality, and GDP per capita in the countries of the HKH region. Some of the variations can be attributed to the policies and implementation strategies of the respective governments and are indicative of how economic growth is tied to equity concerns and expenditure by governments in the social sector.

The conventional wisdom is that an increased level of final energy consumption is an indication of economic progress and better quality of life of a nation. However, close observation of the relationship between energy consumption per capita, HDI, industrialisation ratio (IR), and urbanisation ratio(UR) in the countries of the HKH

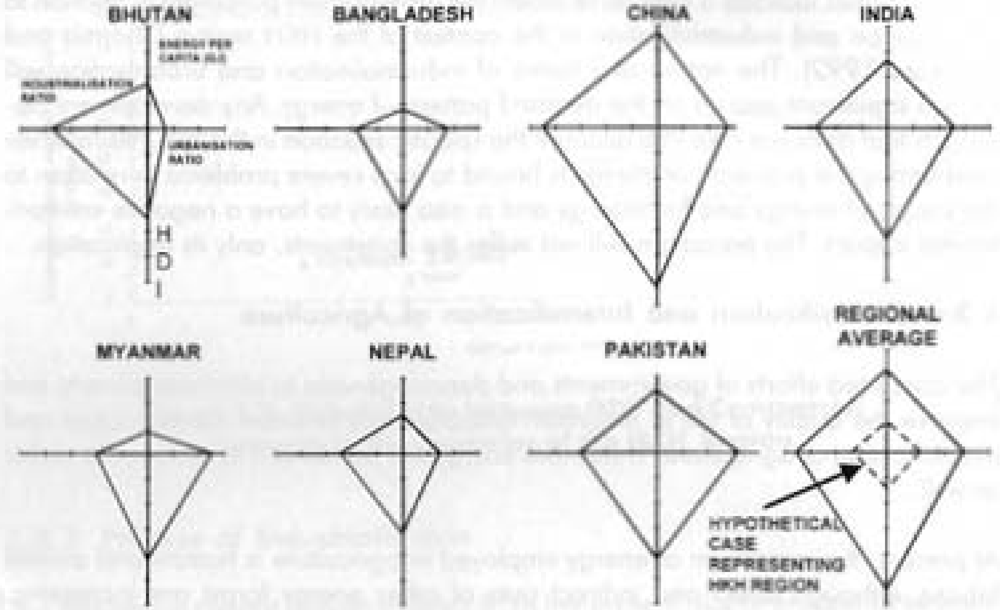

Figure 1.9: Relationship between HDI, Energy Consumption, Industrialisation Ratio, and Urbanisation ratio

region shows that the relationship is not necessarily this simple (Fig. 1.9). The variation observed between the different countries indicates that the availability of energy resources and technologies alone does not necessarily lead to achievement of the desired level of human development.

1.4 Constraints in the Development of the Energy Sector

The following are examples of constraints in the development of energy sector in the countries of the HKH region (Ramani et. al. 1995, DeLucia 1994, PEP 1995), though the magnitude of the problem varies from country to country because the strategies adopted for economic growth are different and the level of natural resource endowment, patterns of energy consumption, energy resource mix and technological options adopted vary greatly exhibiting varying degrees of environmental stress at macro- and micro-level.

1.4.1 Policy, Planning and Programming

Electrification always emphasized on fulfilling the lighting loads of administrative headquarters (small towns and periphery) rather than on fulfilling the potential for motive power that would lead to economic transformation of an area. It is considered a welfare package with the price of electricity always subsidized, so much so that these systems are not even capable of collecting sufficient revenue towards meeting the annual operation and maintenance cost.

Policies to promote RETs were initially geared towards reducing the consumption of fuelwood with the intervention of new technologies in the absence of proper evaluation of the multiplicity of traditional technologies and also without regard to socio-cultural aspects of the mountain population. Consumption of fuelwood is considered as a main cause of deforestation though other requirements such as fodder for livestock, land required for cultivation due to low productivity, large-scale felling of timber, and so forth, are never given due attention while designing energy technology options to suit local conditions. At the same time, alleviation of human drudgery and deteriorating health conditions, particularly of women and children, as well as decreasing soil fertility are never considered seriously.

Energy planning investments are mostly biased in favour of large schemes and emphasis is always placed on the expansion of the supply rather than on the potentials of energy demand management. There are no sufficient policies to promote decentralised energy systems and end-use appliances. Also, policies on import duties and foreign capital ignore the importance of renewable energy resources and technologies.

Energy planning models employed are mechanistic in nature. They are mostly conceived in developed countries and do not take renewable energy technological options into consideration.

1.4.2. Technological Capability

There are insufficient technological options to choose from to meet the essential energy needs of the rural people such as cooking, heating and drudgery reducing technologies at affordable prices. Lack of appropriate data on local manufacturing capabilities of RETs and ignorance of the technology transfer process hinder the enhancement of technological capability. Also, research and development investment in renewable energy technologies is minimal.

1.4.3 Cost, Financing and Investment

There is a huge distortion between market price and economic price of renewable energy forms. Thus when comparison is made, traditional and commercial energies employing inefficient technologies are bound to show "better" financial attractiveness than renewable energy technologies. As long as distortion in energy prices exists, there is little scope for renewable energy technologies that are economically cost effective to find their place in these countries. Besides this, high up-front cost of renewable energy technologies as well as prevailing subsidies on commercial fuels prevents the innovation in renewable energy technologies.

Bilateral and multilateral donors are biased towards financing centralised energy supply system rather than multiple decentralised energy programmes. Rigid approach by the donors with regard to "least cost" energy options without due understanding of the implication for low-income groups hampers the growth of decentralised renewable energy resources and technologies.

The national and international financing agencies are hesitant to invest in new energy markets because of risk aversion attitude. The innovative entrepreneurs thus are not in a position to acquire venture capital and financing for initial market creation. The existing credit policies with regard renewable systems do not address and cater to low-income groups and the landless since they require collateral for financing.

1.4.4 Institutional Aspects

The evolution of energy decision-making as a supply-side activity has led to the formulation of centralized energy planning institutions and no planning capability exists in the districts or in provinces. And, there is a lack of energy awareness among demand side agencies, especially in rural and urban development bodies. The voice of a limited number of specialized agencies for renewable energy development are marginalized. Private sector and NGOs have little say over the energy decision-making process.

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Improved cooking stove installed in a hill village in Nepal

Prepared by: K. Rijal

Flight of solar photovoltaic panels, Northern Areas, Pakistan

Parabolic solar cooker installed in a hill village in Nepal

Traditional water mill, Melamchi, Nepal
- CRT

Chapter 2

Energy Use in Mountain Areas - Patterns and Trends

by
Kamal Rijal

2.1 Background

The economies of the Hindu Kush-Himalayan (HKH) region are characterised by low levels of development that are reflected in poverty. Levels of income and development differ within the HKH region both because different countries have adopted different strategies for economic growth, and because the level of natural resource endowment and patterns of energy consumption and mix of energy resources varies greatly. However, throughout the region there is evidence of growing environmental stress. Natural resources, specifically forest and water, are threatened by the food and energy needs of the growing population. The conditions of a subsistence economy are evident in the increasing rate of deforestation.

The livelihoods of mountain communities cannot be made sustainable unless a concerted effort is made geared towards the development of a model that embodies transformation from a subsistence economy to a diversified economic structure (Papola 1996). The model should be based on economic and allocative efficiency and have the twin objectives of poverty alleviation and generation of employment opportunities. Such a transition will inevitably require the development of energy resources and technologies that suit the particular conditions of the mountains.

2.2 Energy Use Patterns in the HKH: Present Trends

1.2.1 The Context

Energy should be seen as a means of fulfilling the social and economic objectives of the people in the HKH region. The development of energy supplies is essential for four main reasons. First, the minimum level of energy services required to meet the basic needs of mountain communities for cooking and space heating must be ensured. Second, provision of energy is essential to meet the social objective of alleviating human drudgery (particularly that of women, children and the economically weak). Third, energy services are required to sustain and support economic activities (both newly emerging and traditional). Finally, the energy supply needs to be developed in such a way that it can play a leading role in increasing the productivity of mountain areas, thus enhancing the economic efficiency of the use of energy resources. A further point is that energy resources that are available in abundance and/or are naturally renewable should be developed as an economic commodity to be marketed to other parts of the country as well as to neighbouring countries so as to enhance the income level of mountain communities and reduce poverty. However, it is equally important to realise that the production, transformation, use, and marketing of energy resources can lead to environmental degradation as well as to detrimental effect on human health.

In the past, the choice of particular energy forms to provide the desired energy services in the mountains was based on the availability of and access to particular energy resources and technologies at affordable prices. Increasing environmental awareness, however, has made the environmental costs associated with the development of energy an important factor in the choice of energy mix. At the same time, the quality and quantity of energy services required and the energy resources available in mountain areas dictate the choice of energy mix to maximise social and economic benefits. It is not that options are not available. The challenge is how to make the right choice. For example, design and execution of an energy activity will impinge on various groups in a society. The different groups with a stake in the activity will respond positively or negatively according to their vested interests.

2.2.2 Energy Services in the Major Sectors

The major sectors consuming energy in mountain areas are households and cottage industries. At present, these sectors use between 84 and 96 per cent of the total energy consumed in the HKH mountain areas of China, India, Nepal, and Pakistan (Figure 2.1).

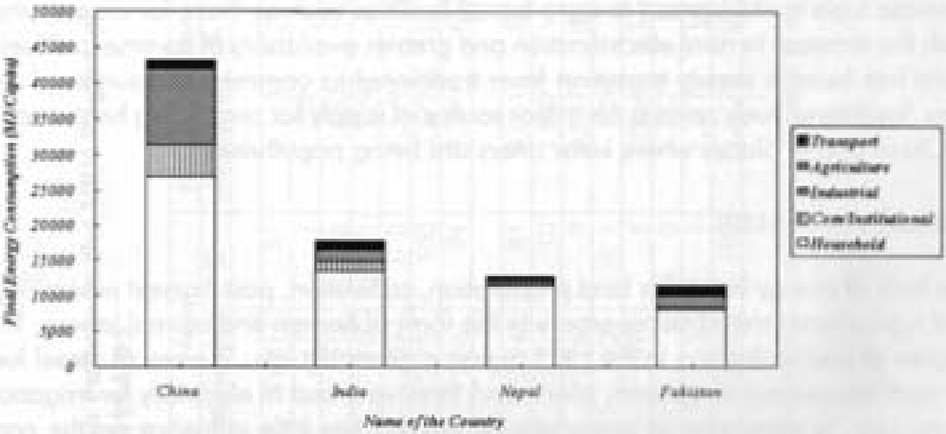

Figure 2.1: Final Energy Consumption Pattern, 1994/95 within the HKH Region of Different Countries

Household Sector

Cooking and heating are the main household energy needs. A variety of traditional cooking and heating stoves fired by biomass fuels is used in mountain households. Purchase of household energy appliances, such as rice cookers, radios, and television sets, depends on income level, cost of appliances, and availability of electricity. Urban mountain households use such equipment more often. Lighting energy needs are met mainly by kerosene and electricity. In mountain areas, demands for space heating are greater than demands for cooking, if a comparison is made in terms of useful energy (for a definition of useful energy refer to Annex A). A typical example is that of Nepal where, in the mountains, 32 per cent of the useful energy required by the household sector is used for cooking and 56 per cent for heating, compared with 40 per cent for cooking and 36 per cent for heating in the hill areas. The remainder, 12 per cent and 24 per cent respectively, is used for lighting, operating electrical appliances, boiling water, and agro-processing activities.

Cottage Industries

The energy needs of cottage industries (such as agro-processing, charcoal production, potteries, bakeries, blacksmiths, sawmills, carpenters' shops, and village workshops) include requirements for lighting, process heat, (i.e., low temperature heat requirement) and motive power. In general the process heat requirements in facilities such as forges, potteries, and bakeries are fulfilled by fuelwood and other biomass fuels, although in the HKH region of China coal is used extensively for this purpose. Motive power requirements are met by electricity, diesel, and kerosene where available, or else by human or animal labour using mechanical equipment. The use of biomass fuels is widespread in agro-based facilities such as those for crop-drying. With the increase in rural electrification and greater availability of commercial fuels, there has been a steady transition from traditional to commercial sources of energy. Traditional fuels remain the major source of supply for processing heat, except in China and in places where solar driers are being popularised.

Agricultural Sector

The bulk of energy inputs for land preparation, cultivation, post-harvest processing, and agriculture-related transport are in the form of human and animal labour. The degree of mechanisation in the HKH region is generally low. The use of diesel fuel for such equipment as tractors, tillers, and threshers, and of electricity for irrigation pump-sets, is increasing in many places, but this has little influence on the consumption of traditional sources of energy, since the energy sources substituted are human and animal labour. The main use of traditional energy sources in the agriculturui sector is for crop-drying, which represents a relatively small part of the total consumption within the sector.

Other Sectors

The other main sectors that require energy services in the mountains are the commercial and transport sectors. The main need of the commercial sector is for energy to fulfill the cooking, heating and lighting requirements of the service sector. The transport sector needs energy to operate different kinds of vehicles, although in many areas human and animal labour are still used extensively as a source of energy for transport.

2.2.3 Final Energy Consumption Patterns

The per capita final energy consumption in the HKH regions of China, India, Nepal, and Pakistan are shown in Table 2.1, the values for each country as a whole in Table 1.4. Per capita consumption in the HKH region is lower than the country average in India and Pakistan and comparable to the national average in China. The values for Nepal are the same, as the whole country is taken to be in the HKH region. In all countries the percentage of per capita energy consumption coming from biomass fuels (Figure 2.2) is substantially higher in the HKH region than in the country as a whole. For example, in India biomass fuels contribute 79 per cent of the total in the HKH region compared to 47 per cent in the whole country. These figures reflect the fact that, in general, the mountain regions are marginalised in terms of access to commercial fuels and are heavily dependent on biomass fuels, to the extent that a large proportion of agricultural residues and animal dung may be diverted from the farm to the fire. The situation is worsened by the low level of efficiency of utilisation of these fuels, and the creation of health hazards — particu-

Table 2.1: Per Capita Final Energy Consumption Pattern in the HKH Region of Different Countries, FY 1994/95

Descriptions	HKH in China		HKH in India		Nepal		HKH in Pakistan	
	MJ/capita	%	MJ/capita	%	MJ/capita	%	MJ/capita	%
By Sector								
Domestic	26,857	62	11,045	76	11,515	91	8,163	70
Commercial/Inst.	4,440	10	568	4	172	1	258	2
Industrial	10,515	24	1,705	12	613	5	1,580	14
Agricultural	187	<1	220	1	100	<1	229	2
Transport	1,216	3	1,070	7	327	3	1,349	12
Total	43,214	100	14,607	100	12,727	100	11,577	100
Total	21,983	51	11,486	79	11,561	91	7,590	65
By Fuel Type								
Fuelwood	12,688	29	9,644	66	10,246	81	6,051	52
Other Biomass	9,295	22	1,842	13	1,315	10	1,539	13
Commercial fuels	21,232	49	3,121	21	1,166	9	3,987	35
- Coal	16,370	38	53	<1	139	< 1	179	2
- Petroleum Fuels	1,981	5	2,226	15	890	6	1964	17
- Natural Gas	410	<1	0	0	0	0	727	6
- Electricity	2,271	5	842	6	137	1	1,117	10
Total	43,215	100	14,607	100	12,727	100	11,577	100

Sources: Estimates based on Abdullah 1997; Bansal 1997; Banskota and Sharma 1997; Mengjie et al. 1997

larly for women who are the managers, producers, and users of energy at the household level.

The main sources of energy within the HKH region are biomass fuels and commercial fuels, although the percentage of utilisation of these fuels varies widely between the different countries (Table 2.1). The total per capita consumption of energy in the HKH region of China is almost four times higher, and the consumption of biomass fuels more than double, that in the HKH regions of India, Nepal, and Pakistan. The consumption of energy by households in the HKH region of China is more than double consumption in India, Nepal, and Pakistan and consumption by the com-

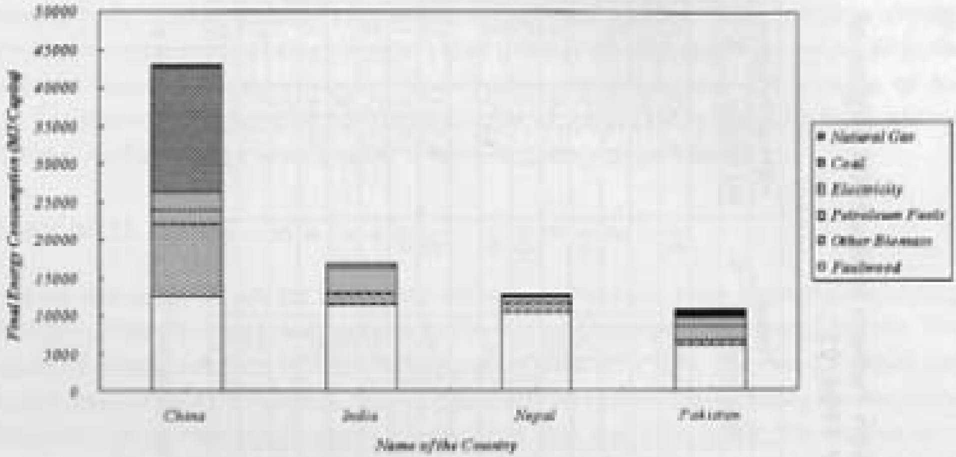

Figure 2.2: Final Energy Consumption Pattern, 1994/95 within the HKH Region of Different Countries

mercial and industrial sectors almost 10 times more than that in the other countries.

These patterns are discussed in more detail for each country separately in the following paragraphs.

The HKH Region of China

The per capita final energy consumption in the HKH region of China (43.2 GJ) is similar to that for China as a whole, but the share of biomass fuels is very different, 51 per cent compared to 22 per cent. Seventy-nine per cent of the total biomass fuel consumed in the HKH region is consumed by the household sector (Table 2.2). The higher level of consumption of biomass fuels in the mountains is not only attributed to the harsh climatic conditions but also to the high price of commercial fuels, the low purchasing power of the mountain population, and the fact that biomass fuels are available 'free' even though time is required for their collection. Coal contributes about 78 per cent of the energy from commercial fuels (Figure 2.3). These figures clearly reflect the low level of economic development of the region, with less diversification in the mountain economy, a low level of commercialisation of farming activities, poor accessibility in terms of marketing facilities, and a generally low level of income.

The per capita energy consumption per sector and fuel type are shown in Table 2.2 and Figure 2.3. The household sector depends primarily on biomass fuels, and this will remain so for the foreseeable future. There is a similar trend in the commercial

Table 2.2: Per Capita Final Energy Consumption Pattern in the HKH Region of China, FY 1994/95

Descriptions	Biomass Fuels			Commercial Fuels			Total Energy		
	MJ/capita	Percentage		MJ/capita	Percentage		MJ/capita	Percentage	
		Column	Row		Column	Row		Column	Row
By Sector									
Domestic	17,472	79	65	9,385	45	35	26,857	62	100
Commercial/Institutional	1,724	8	74	2,716	13	26	4,440	10	100
Industrial	2,787	13	26	7,728	36	71	10,515	24	100
Agricultural	0	0	0	187	<1	100	187	<1	100
Transport	0	0	0	1,216	6	100	1,216	3	100
Total	21,983	100		21,232	100		43,215	100	
Total Population (thousands)							19,700		

Source: Mengjie et al. 1997

and institutional sectors, although a more rapid transition in fuel mix can be envisaged as market forces and the willingness to pay for energy increase. The industrial sector, however, depends primarily on commercial energy, mainly coal (71 per cent i.e., 78% of commercial energy) rather than biomass fuels as do the agricultural and transport sectors.

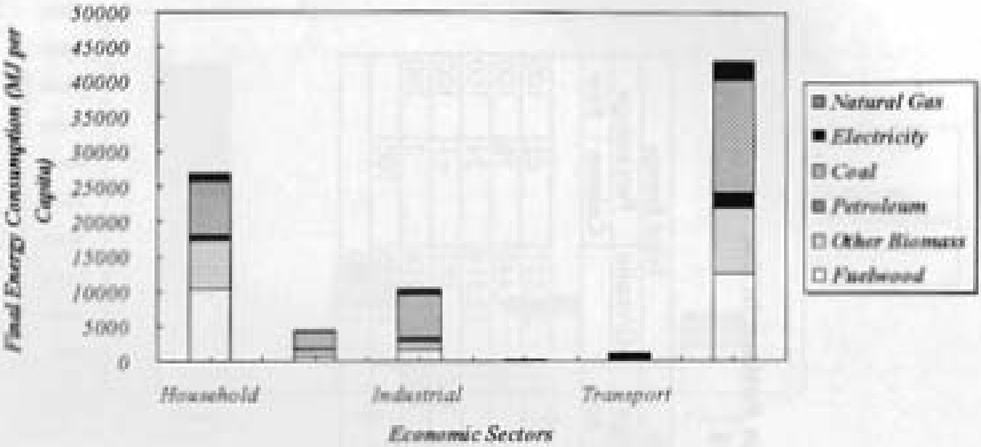

Figure 2.3: Final Energy Consumption by Economic Sector in the HKH Region of China

The pattern of energy use in the HKH region of China shows the following trends: a) the household, commercial, and institutional sectors depend primarily on biomass fuels; b) agricultural residues and animal dung (including biogas) account for almost 42 per cent of the total biomass fuels; c) the industrial and agricultural sectors depend on coal as their main source of energy; d) the transport sector depends primarily on petroleum fuels (51%) and electricity (36%); e) the contribution of renewable energy technologies (excluding biogas) to the total energy consumption amounts to less then one per cent, although its contribution in the industrial sector is more than two per cent and shows an encouraging trend; and f) the household sector is still the greatest consumer of commercial energy (45%), followed by the industrial sector (36%).

The HKH Region of India

The total per capita final energy consumption in the HKH region of India is 14.6 GJ (Figure 2.4). There is little difference between the eastern and western mountains[2] in total per capita energy consumption, but the share of various forms of energy differs somewhat (Table 2.3). Wood is the main fuel in both areas. Petroleum fuels contribute more than 70 per cent of commercial fuels. There is a heavy dependence on fossil fuels (18% in the eastern and 24% in the western mountains) rather

[2] The eastern mountains in India include Sikkim, Darjeeling, and the North East Region of India. The western mountains include Uttarakhand, Himachal Pradesh, and Jammu & Kashmir. This classification is based on the availability and reliability of data and information.

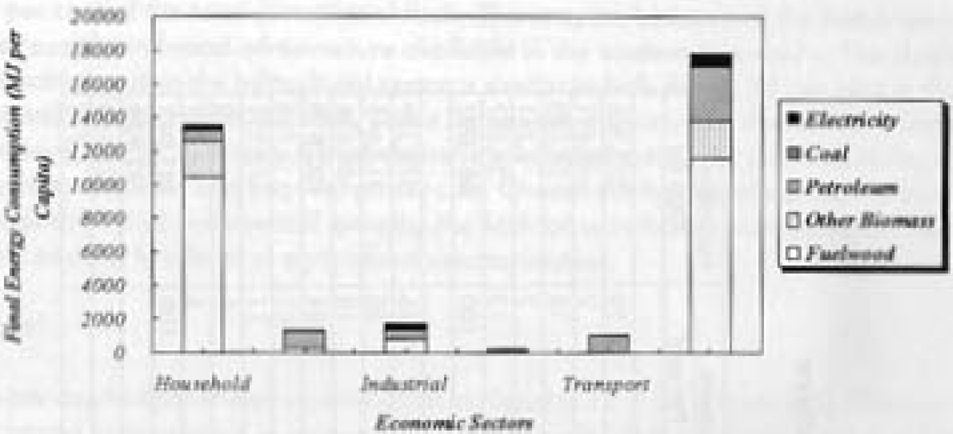

Figure 2.4: Final Energy Consumption by Economic Sectors in the HKH Region of India

than renewable energy, even though the latter (mainly hydropower) is available in surplus. Renewable energy has a potential to generate revenue for the mountain population, as well as being environmentally less damaging than fossil fuels.

Although the eastern and western mountains consume almost equal amounts of final energy per capita, the proportion of energy used by different sectors varies considerably. In the eastern mountains the household sector consumes 78 per cent of total final energy, in the western mountains only 56 per cent. Per capita consumption of fuelwood is higher in the eastern mountains, whereas that of 'other' biomass fuels is higher in the western mountains. The per capita final energy consumed by the industrial and transport sectors in the western mountains is higher than that in the eastern mountains (29% compared to 17%). The per capita consumption of commercial fuels is slightly higher in the west (24% compared to 18%). These trends reflect both the appalling forest conditions in the western mountains and the inadequate commercial energy supply infrastructure and the low level of industrial development and transport infrastructure in the east. The penetration of new and renewable energy technologies in both mountain areas is nominal.

Within each sector, the proportion of energy supplied by different sources also varies. The household sector in both mountain areas depends primarily on biomass fuels (more than 90%), though the contribution of commercial fuels is slightly higher in the western mountains than in the east (8% versus 5%) (See Chapter 4 for details). The industrial and commercial sectors still depend on biomass fuels for more than 50 per cent of their energy requirements in both areas. In the eastern mountains, petroleum fuels account for almost 63 per cent of the commercial fuels used by the industrial sector, whereas, in the western mountains, electricity contributes

Table 2.3: Per Capita Final Energy Consumption Pattern in the Mountains of India, FY 1994/95

Categories	Eastern Mountains		Western Mountains		Mountain Total
	MJ/capita	Per cent	MJ/capita	Per cent	'000 GJ
Sector					
Household	11,064	78	11,030	56	363,766
Commercial/Institutional	556	4	577	2	18,691
Industrial	1,500	11	1,869	16	56,142
Agricultural	140	1	284	2	7,241
Transport	883	6	1,221	13	35,257
Total	**14,143**	**100**	**14,981**	**100**	**481,097**
Fuel Type					
Total biomass	11,581	82	11,410	76	378,279
- Fuelwood	10,817	77	8,705	58	317,645
- Other Biomass	764	5	2,705	18	60,634
Total Commercial Fuels	**2,562**	**18**	**3,571**	**24**	**102,818**
Coal	24	<1	77	<1	1,758
Petroleum Fuels	1,818	13	2,554	17	73,331
Natural Gas	0	0	0	0	0
Electricity	720	5	940	6	27,729
Total	**14,143**	**100**	**14,981**	**100**	**481,097**
Total Population (Thousands)	**14,662**		**18,274**		**32,936**
Rural	12,100		15,060		27,160
Urban	2,562		3,214		5,776

Sources: Study estimates based on Bansal (1997) and Rijal (1996).

50 per cent of the total commercial fuels. This may be because of the better electricity supply and road infrastructure available in the western mountains. The share of electricity within the agricultural sector is similar in both areas, 38 per cent in the east and 34 per cent in the west. These figures are indicative of the lack of a farm gate level electricity supply infrastructure in mountain areas, the poor reliability of electricity supplies, and frequent power cuts. Overall the figures reflect the low level of industrial and commercial growth, the lack of a sufficient transportation network, and the low level of agricultural mechanisation.

Nepal

The per capita final energy consumption in Nepal is 12.7 GJ (Figure 2.5). The total per capita consumption in eastern and western parts[3] of the country is similar, but the share provided by the various forms of energy is different (Table 2.4). Fuelwood supplies 76 per cent of energy requirements in the east and almost 89 per cent in the west, whereas the consumption of 'other' biomass fuels is higher in the east (13% compared to 7%). In both parts of the country, petroleum fuels contribute more than 70 per cent of the commercial fuels used. The proportion of energy used by different sectors also varies considerably. The rural household sector consumes 80 per cent of the total final energy in the east and 90 per cent in the west. All sectors other than households consume more final energy per capita in the east than in the west. Finally, although low in both areas, the per capita electricity consumption in the east is 4.5 times higher than that in the west. These figures reflect

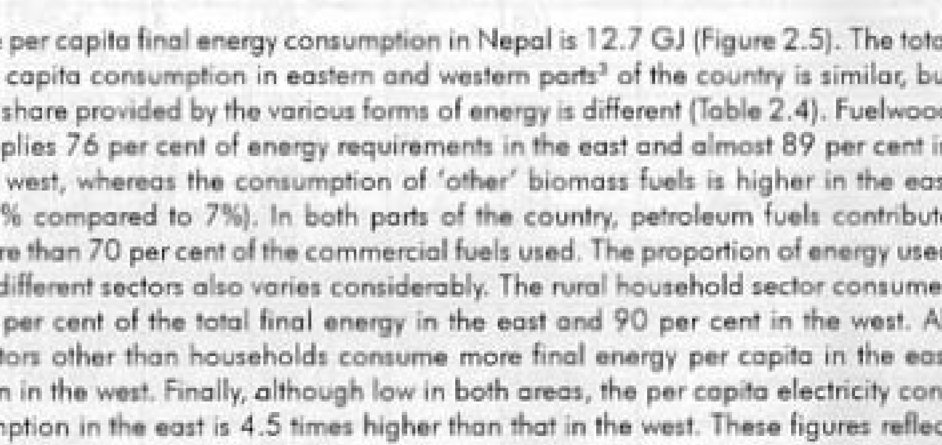

Figure 2.5: Final Energy Consumption by Economic Sectors in Nepal

[3] The eastern part of Nepal includes the Eastern and Central Development Regions. The western part includes the West, Mid-west, and Far-west Regions.

Table 2.4: Per Capita Final Energy Consumption Pattern in Nepal, FY 1994/95

Categories	Western Nepal		Eastern Nepal		Nepal '000 GJ
	MJ/capita	Per cent	MJ/capita	Per cent	
Sector					
Rural Domestic	12,713	90	11,635	80	219,116
Urban Domestic	8,679	5	6,046	7	15,361
Commercial/Institutional	135	1	199	2	3,511
Industrial	291	2	848	7	12,478
Agricultural	95	<1	104	<1	2,035
Transport	108	<1	486	4	6,649
Total	13,047	100	12,492	100	259,149
Fuel Type					
Total Biomass Fuels	12,407	95	11,082	89	237,045
Fuelwood	11,543	88	9,437	76	210,245
Other Biomass	864	7	1,646	13	26,800
Total Commercial Fuels	640	5	1,410	11	22,104
Coal	97	<1	170	1	2,840
Petroleum Fuels	498	4	1,036	8	16,474
Natural Gas	0	0	0	0	0
Electricity	45	<1	204	2	2,790
Total	13,047	100	12,492	100	259,149
Total Population (Thousands)	**8,593**		11,769		**20,363**
Rural	7,966		10,128		18,095
Urban	627		1,641		2,268

Source: Based on Banskota and Sharma (1997)

the comparatively better condition of the forests and the low level of industrial development and transport infrastructure in the west, as well as differences in the supply infrastructure for commercial fuel in both these areas.

Within each sector, the proportion of energy supplied by different sources also varies. (See Chapter 5 for details). The household sector in the whole mountain area (both the hills and the mountains as defined in ecological terms) depends primarily on biomass fuels (more than 95%). However, per capita fuelwood consumption in the mountains is almost double that in the hills (1047kg versus 563kg). This is partly because of the colder climate, and partly the result of the greater availability and better condition of forests. Final per capita energy consumption in the household sector is almost three times higher in rural areas of the mountain areas than in urban areas of Nepal. This is because commercial fuels provide 43 per cent of the total energy requirements in urban areas compared to less than four per cent in rural areas of the mountains. Commercial fuels have a much higher conversion efficiency (40-80%) for commercial fuels compared to 10-20 per cent for biomass fuels.

The industrial sector of the Nepalese economy still depends primarily on biomass fuels, which meet about 60 per cent of the total energy requirement. The per capita final energy consumption of the industrial and transport sectors is four times higher in the east than in the west. This reflects the overall industrial development pattern, rather than the prevalence of energy intensive industries in the east. The greater industrial development in the east may be the result of the better electricity supply and road infrastructure available and the lower cost of transporting imported industrial raw material, as the eastern area is closer to accessible sea-ports in India. The agricultural sector is dependent primarily on animate energy. Petroleum fuels, used mainly to operate farm machinery, dominate amongst the commercial fuels both as a result of the lack of an electricity supply network and the need for decentralised energy systems at the farm-gate level.

The HKH Region of Pakistan

The per capita final energy consumption in the mountains of Pakistan is 11.6 GJ (Figure 2.6). The total per capita energy consumption is almost 1.5 times higher in the western mountains than in the northern mountains[4], 15.1 GJ compared to 10.5 GJ. This is almost entirely because of higher domestic consumption, the per capita consumption in the commercial, industrial and agricultural sectors is somewhat higher in the northern mountains. The household sector consumes about 80 per cent of total final energy in the western mountains and less than 70 per cent in the northern mountains. The share provided by the various forms of energy is different in the two areas (Table 2.5). Fuelwood provides 46 per cent of total final energy in the northern mountains and 66 per cent in the western mountains, reflecting a much higher per capita consumption in the west. This is the result of the harsh climatic conditions in the western mountains, and despite the fact that fuelwood is scarce and the area depends mainly on imports from outside Balochistan province. Residents of the northern mountains are also tempted to save fuelwood to earn cash incomes through export to the adjoining plains where there is a big demand and wood fetches a good price. The total per capita amount of commercial fuels consumed in the two areas is similar.

The rural household sector in the mountain areas of Pakistan depends primarily on biomass fuels (98%) in the western and 92 per cent in the northern mountains (see Chapter 6 for details). The dependence on biomass fuels is less in the urban household sector (50-55%) where there are different patterns of energy demand and supply infrastructure. The main commercial fuels used in the urban household sector in the northern mountains are natural gas (70%) and electricity (22%). In the

[4] The northern mountains of Pakistan include the NWFP, FATA, the Northern Areas, and Azad Jammu and Kashmir. The western mountains include Balochistan.

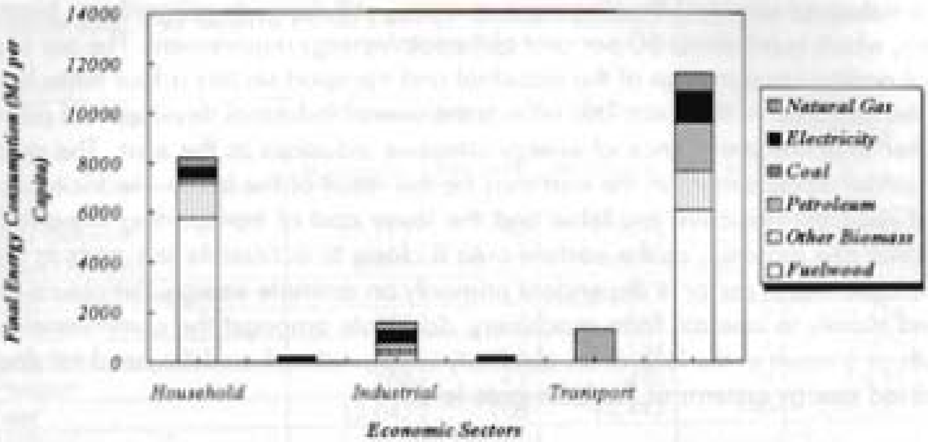

Figure 2.6: Final Energy Consumption by Economic Sectors in the HKH Region of Pakistan

Table 2.5: Per Capita Final Energy Consumption Pattern in the Mountains of Pakistan, FY 1994/95

Categories	Western Nepal		Eastern Nepal		Nepal '000 GJ
	MJ/capita	Per cent	MJ/capita	Per cent	
Sector					
Rural domestic	12,024	65	7,028	56	204,884
Urban domestic	11,835	14	7,024	11	37,087
Commercial/Institutional	222	1	268	2	7,639
Industrial	1,350	9	1,648	16	46,886
Agricultural	202	2	236	2	6,785
Transport	1,393	9	1,335	13	40,019
Total	15,186	100	10,571	100	343,550
Fuel Type					
Total Biomass Fuels	11,096	73	6,561	62	225,259
Fuelwood	10,093	66	4,864	46	179,572
Other Biomass	1,003	7	1,697	16	45,687
Total Commercial Fuels	4,090	27	4,010	38	118,291
Coal	585	4	59	1	5,304
Petroleum Fuels	2,102	14	1,923	18	58,271
Natural Gas	421	3	871	8	21,570
Electricity	982	6	1,157	11	33,146
Total	15,186	100	10,571	100	343,550
Total Population (Thousands)	**6,738**		**22,937**		**29,675**
Rural	5,526		19,699		25,225
Urban	1,212		3,238		4,450

Source: Based on Banskota and Sharma (1997).

western mountains the emphasis is reversed with electricity providing 51 per cent and natural gas 33 per cent. The per capita electricity consumption in the urban household sector of the western mountains is almost four times than in the northern mountains, even though the total per capita electricity consumption in the northern mountains is 1.2 times higher than in the western mountains.

The industrial sector of the mountain economy of Pakistan relies mainly on commercial fuels for energy (70-80%). The main commercial fuels used are in the western mountains coal (54%) and, in the northern mountains, natural gas and electricity.(69%). The agricultural sector consumes more electricity in the northern mountains (168 MJ per capita) than in the western mountains (111 MJ per capita). This reflects both the extent of agricultural mechanisation and the electricity supply situation in these areas.

Trends in Energy Use in the HKH Region

In general, the pattern of energy use in the HKH region shows the following trends: i) biomass fuels dominate the energy scene, with fuelwood being the principal source of energy; ii) the household sector is a major consumer of energy; iii) energy demand is increasing as a result of agricultural diversification and intensification, rural industrialisation, and an increasing number of tourists (Banskota and Sharma 1997a); iv) energy use in mountain households varies with the household size, altitude, ethnic group, income and expenditure, land holding, livestock holding, and number of cooking stoves employed (Rijal et al. 1990; Rijal 1991); v) the requirement for heat energy, primarily for cooking and heating, is higher than that for energy for shaft power as an input to a production process; vi) the demand for fuelwood exceeds the sustainable supply, and thus the process of destruction at the margin is a common phenomenon in a large part of the region; vii) the cost of energy extraction is increasing; viii) the availability of fuelwood is decreasing and the time taken for its collection is increasing; ix) continuous unsustainable use of fuelwood from the forest forces rural people to use 'other' biomass fuels (agricultural residue and animal dung), further degrading the environment; and x) access to and availability of energy technologies are improving, but not enough as yet to show a reduction in human drudgery.

Given these trends in energy consumption, the major policy issue faced by planners in the HKH region is to decide what type of energy use pattern or mix would be sustainable environmentally and financially in the mountains.

2.3 Patterns of Energy Resource Availability in the Mountains

The per annum potential of renewable energy resources (primarily hydropower and fuelwood, and excluding solar and wind) in the Hindu Kush-Himalayan region is two to four times higher than the present day requirements for total energy (3,457 Million GJ versus 851 Million GJ in the HKH region of China; 1388 Million GJ versus 588 Million GJ in the HKH region of India; 1519 Million GJ versus 259 Million GJ in Nepal; and 654 Million GJ versus 344 Million GJ in the HKH region of Pakistan; Table 2.6). Present day production of hydropower in the HKH region is only one per cent of the total theoretically available in China and Nepal, less than four per cent in India, and about 16 per cent in Pakistan. In contrast, the extraction of fuelwood exceeds the sustainable supply in the whole of the HKH region, with a few exceptions in isolated pockets, such as the eastern mountains of India, and places where accessibility limits the extraction of fuelwood and timber to meet the demands of the adjoining plains.

In the HKH regions of China, India, and Pakistan, the potential non-renewable energy is comparable with the potential energy from hydropower. In contrast, the amount of fossil fuels available in Nepal is insignificant. Thus there are consider-

Table 2.6: Energy Potential and Production Per Annum in the HKH Regions of China, India, Nepal, and Pakistan, FY 1994/95

Description	Unit	China	India	Nepal	Pakistan
Proven Reserves					
- Oil	Million GJ	N. A	6682	0	932
- Coal	Million GJ	N. A	9141	0	1568
- Natural Gas	Million GJ	N. A	5621	0	4160
Production per annum					
- Oil	Million GJ	12	219	0	0
- Coal	Million GJ	315	35	0	50
- Natural Gas	Million GJ	276	74	0	353
Life of Reserves					
- Oil	Years		31		
- Coal	Years		262		32
- Natural Gas	Years		76		12
Hydropower					
- Potential	Million GJ	3207	1007	1309	473
- Production	Million GJ	22	36	4	75
Forest Situation[1]					
- Total Forest Area	Sq. km.	215081	207484	42910	42240
- % of Geographical Area	%	13	37	29	14
- Fuelwood Extraction	Million GJ	250	381	210	181
Total Potential Per Annum	Million GJ	6713	1716	1519	1057
- Non-renewable	Million GJ	3256	328	0	403
- Renewable	Million GJ	3457	1388	1519	654
- Fuelwood	Million GJ	250	381	210	181
- Hydropower	Million GJ	3207	1007	1309	473

[1] Figures for Nepal show the accessible forest area.

able variations in the patterns of energy availability in the region. And a similar variation exists between different regions of each country. In general, the availability of renewable energy increases and the availability of non-renewable energy decreases with increased elevation.

2.3.1 The HKH Region of China

The annual production of non-renewable fuels in the HKH region of China exceeds by almost 2.5 times the total production of electricity and fuelwood. At the same time the potential of hydropower alone is five times the present day annual production of non-renewable fuels. At present, less than one per cent of the total potential hydropower is being exploited. The oil reserves available in China as a whole will last for more than 100 years at present day oil consumption rates, whereas the reserves of natural gas will last less than 35 years. Total forest cover in the HKH region of China is 13 per cent of the total geographical area, with about one ha of forest area per capita. The solar radiation available is quite good, varying from 150 to 200 kcal per cm^2 per year, and there are about 760 geothermal spots with temperatures ranging from 50 to 120°C.

2.3.2 The HKH Region of India

It is estimated that the oil reserves within the HKH region of India will last for 31 years and natural gas reserves will last for 76 years, if the present level of production is maintained. Almost all of these resources are taken out of the HKH region to meet the industrial, transport, and agricultural demands of other parts of the country. The coal reserves available in the eastern part of the HKH region of India could last for more than 200 years. More than 75 per cent (64,000MW) of the hydropower potential of India lies within the HKH region, although only about 2300MW is exploited at present. Almost 37 per cent of the total area of the HKH region in India is covered by forests but the distribution is very uneven, with 69 per cent forest cover in the eastern and only about 16 per cent forest cover in the western mountains (Box 2.1).

2.3.3 Nepal

There are no proven reserves of oil in Nepal, though petroleum exploration activities began in 1979 with the expectation of finding natural oil and gas in the foothills of southern Nepal. There is a proven reserve of natural gas of 47.6 million m^3 (1.7 million GJ) in the Kathmandu Valley. Similarly, there are small deposits of lignite in the Kathmandu Valley and eocene coal in Dang district. These are being exploited in small quantities and do not contribute significantly to the national energy demand. The estimated area of accessible forest in Nepal is 42,910 sq. km., of which 15 per cent falls within the Terai, 54 per cent in the hills, and 31 per cent in the mountains. The theoretical potential of hydropower is 83,000MW, of which 13 per cent is from small rivers. The technically feasible potential of hydropower is 42,000MW. At present, the total number of hydroelectric plants of all sizes (public and private) is reported to be 356 and their total capacity is about 254MW. Only about four per cent of the rural population has access to electricity, and most rural households consume less than 11kWh per month.

Box 2.1: State of Forests in the HKH Region

The HKH region of India: There is a substantial difference between the recorded forest area and actual forest cover (for details refer to Table 4.1) in the hills and mountains of India. Actual forest cover is about 60 per cent of the recorded forest area in the western part of the HKH, but 127 per cent in the eastern part. The difference between the recorded area and actual forest cover in the whole HKH region of India is only about two per cent. The forest area available per capita is 0.6 ha, 0.85 ha per capita in the eastern part and 0.32 ha per capita in the western part of the HKH. The situation differs widely at district and state level. The forest area available per capita is 7.9 ha in Arunachal Pradesh, 0.34 ha in Jammu and Kashmir, 0.38 ha in Uttarakhand, 1.3 ha in Uttarkashi, and 0.23 ha in Nainital.

Nepal: The accessible forest area per capita is 0.37 ha in the mountains, 0.29 ha in the hills and, 0.13 ha in the *Terai*. The mapped forest area available per capita (includes the area for potential forest regeneration) is 0.93 ha in the mountains, 0.58 ha in the hills, and 0.34 ha in the *Terai*. Substantial quantities of fodder and fuelwood are extracted from farm land. The estimated sustainable supply of fuelwood in Nepal is 7.5 million air-dried tonnes per annum (366kg per capita, compared to an average overall fuelwood consumption of 640kg per capita).

The HKH region of Pakistan: Public forest areas in the HKH region (76% of total forest area in Pakistan), which include coniferous forests (58%), scrub (33%), riverain forests (1%), farmland trees (4%), and irrigated and linear plantations (4%), provide most of the wood required for domestic and industrial purposes within both the mountains and plains of Pakistan. The northern and western mountains contribute 82 and 18 per cent respectively of the total mountain forest area. About 14 per cent of the northern mountains is covered by forest, although there is a significant variation at district level from 15 to 60 per cent . The northern mountains are dominated by coniferous forest (70%) and scrub (21%) and the western mountains by scrub forest (85%). In the mountains, coniferous forest contributes almost 51per cent, farmland trees 25 per cent, and scrub forest nine per cent of potential supplies (annual sustainable yield).

2.3.4 The HKH Region of Pakistan

There is no production of oil in the HKH region of Pakistan and there is a uniform fixed price for oil products. However, availability of oil in distant mountain areas may be problematical. The main gas fields in the western mountains are located in Sui, Pirkoh, and Loti. The annual production of gas from these fields has remained nearly constant during the last five years at 325,000 to 350,000 million cu.ft.. There are 5,293km of gas distribution pipeline in mountain areas (60% in the northern and 40 per cent in the western mountains). In the FY 1994/95, 1.6 million tonnes of coal were produced in the mountains, 97.4 per cent in Balochistan. The estimated reserves of coal in mountain areas are 54 million tonnes. The northern mountains are rich in hydropower resources. According to some estimates these areas have a potential of 30,000MW. The Master Plan for the development of small hydropower identified 116 sites as feasible with a total potential of 400MW.

2.3.5 Issues Related to Energy Resources

The analysis of energy resource availability shows clearly that the mountain areas possess sufficient renewable energy resources, distributed evenly throughout the region. In general, renewable energy resources have the following distinct features: i) low energy density; ii) low calorific value; iii) high bulk density; iv) low grade of energy, primarily available as heat energy in its natural form; v) low conversion efficiency; and vi) high cost of conversion. These features make mountain energy resources vulnerable in terms of use of the energy for productive purposes, but suitable for meeting the various needs of communities at subsistence level.

Selected pockets of mountain areas do possess fossil fuels. These are essentially non-renewable. Extraction is costly and, in some instances, the amount available is quite insignificant so that exploitation is not economically viable.

Another important issue is that, although the mountain areas possess renewable resources such as fuelwood, rapid degradation and extraction of these resources beyond their regenerative capacity, not only for local use but also to meet the demands of the adjoining plains, make these resources non-renewable and no longer sustainable. The pertinent question is how these biomass resources can be made sustainable.

2.4 New and Renewable Energy Systems

The new and renewable (non-depleting source) energy systems used within the HKH region are primarily: biomass related technologies (improved cooking stoves, biomass gasifiers, biogas plants), solar technologies (solar cookers, photovoltaic (PV) systems for water pumping and lighting, solar water heaters, solar greenhouses, solar driers), wind pumps and turbines, and mini- and micro-hydropower. Table 2.7 summarises the number of such installations within the HKH regions of China, India, Nepal, and Pakistan. The figures shown are the cumulative number of plant installations, but it is difficult to identify how many of them are operational. A review of a number of evaluation reports indicates that some of these technologies are gaining momentum in some areas but have failed in others for various reasons. For example, the biogas programme can be considered quite successful in Nepal and China, although there are also a number of constraints to steady growth, but it has failed in Pakistan and Bangladesh. Mini- and micro-hydropower development is gaining momentum in Pakistan and India, although there has been a decline in the number of installations in Nepal. There have been mixed results with improved cooking stoves within the HKH region.

In the following paragraphs, the status of new and renewable energy systems in the HKH regions of the separate countries is discussed, and the pertinent issues then summarised.

Table 2.7: Installation of Renewable Energy Technologies in the HKH Region

Technology	Unit	India[1]	China	Nepal	Pakistan
Family-size Biogas Plants	No. of Units	245,067	82,624	32,000	1,134
Improved Cookstoves	No. of Units	939,844	1,541,325	90,000	68,000
Solar Thermal Systems	Sq. m.	2,958	111,288	>10,000	n.a.
- Industrial type	Sq. m.	1,176	n.a.	n.a.	n.a.
- Domestic type	Sq. m.	1,782	n.a.	n.a.	n.a.
Solar Cookers	No. of Units	14,371	60,000	n.a.	n.a.
Solar Greenhouses		n.a.	3,900	n.a.	n.a.
PV Water Pumps	kWp	4	n.a.	30	n.a.
PV Systems	kWp	372	n.a.	300	234
Wind Turbine	MW	n.a.	n.a.	n.a.	n.a.
Mini- and Micro-hydropower	MW	52	n.a.	8.6	18.8

[1] Information on biogas and wind power is up to March 1996; on improved cooking stoves, PV water pumps, mini- and micro-hydropower, and biomass gasifiers up to April 1995; and on solar thermal systems, solar cookers, and PV systems up to March 1993. Information for Uttarakhand and hill districts of West Bengal and Assam are not included.

2.4.1 The HKH Region of China

The development of new and renewable energy technologies in the HKH region of China is quite impressive in terms of the number of installations, though it is not clear what percentage of these are functional. There are about 82,624 family-sized biogas plants, 1.5 million improved cooking stoves, 111,288 sq.m. of solar water heaters, 60,000 solar cookers, and 3,900 sq.m. of solar greenhouses. During the mid nineties, five million sq.m. of passive solar building was built in China.

This type of building reduces the need for coal by 20-40kg per m^2 per year. The initial building costs are 15-20 per cent higher than for 'normal' houses. In Tibet, most of the public sector residential houses have been retrofitted with sun spaces and trombe walls.

The pace of dissemination of new and renewable energy technologies is slower in the HKH region of China than in the rest of the country. China has a strong manufacturing capability for these technologies, but large-scale diffusion is hampered in the HKH region by the lack of institutions to promote the technologies and a low level of acceptability as a result of the socioeconomic conditions in the region.

2.4.2 The HKH Region of India

Improved cooking stoves and family-sized biogas plants are the most common renewable energy technologies in the HKH region of India (Table 2.7). Various evaluation reports indicate that the percentage of functional biogas plants in different states varies from 50-65 to 65-90 per cent. There is a significant potential for using solar energy technologies in the western mountains, and a number of private and public institutions are promoting such technologies. The Indian mountains should also be a good place to install mini- and micro-hydropower plants. The potential in these areas is around 2,000MW, although at present only about 52MW are exploited.

Manufacturing of various renewable energy systems has matured in India as a result of the promotional efforts of the government. There are 74 manufacturers of solar photovoltaic (PV) and wind power systems. Although they are all located outside the HKH region, they are capable of providing services within the region as well. Household biogas systems were initially installed all over India by the Khadi and Village Industries' Commission (KVIC). The role of KVIC has diminished significantly since 1984 with the advent of Deenbandhu fixed, dome-type biogas plants, and today KVIC plays only a minor role. The Ministry of Non-Conventional Energy Sources (MNES) and its nodal agencies is now the main institution responsible for dissemination of biogas technology in India. Improved cooking stoves are produced by local craftsman. Biomass gasifier designs are available, and there are several factories in India, located in different regions, capable of producing such units.

2.4.3 Nepal

There are 32,000 biogas plants installed in Nepal, and more than 90 per cent of them are functional. There are about 947 micro-hydropower units, used mainly for agro-processing activities (8.6MW), and 311 units installed with a capacity of 2.65MW of electricity generation. About 90,000 improved cooking stoves have been installed. More than 10,000 sq.m. of solar water heaters have been installed in the residential and commercial sectors.

The development of solar water heaters is primarily in the private sector and is expanding without any subsidy programmes. Micro-hydro and biogas programmes are considered to be the most successful of the various renewable energy technologies in Nepal, but subsidies are provided for these systems by the government and donor agencies. Private entrepreneurs and non-governmental organizations (NGOs) have shown an interest in disseminating solar PV systems. These systems are gaining popularity in some areas of Nepal.

2.4.4 The HKH Region of Pakistan

Although there are no figures available on the exact extent and nature of new and renewable energy resources in the mountain areas of Pakistan, data on the number of sunny days and some measured insolation values indicate that there is a high potential for solar energy. The mountain areas of Pakistan are also fortunate in terms of their potential for mini- and micro-hydropower (MMHP), about 500MW. MMHP plants have been quite successful in the mountains and about 245 plants with a total capacity of 18.8MW have been installed by various governmental and non-governmental organizations. A variety of designs for improved cooking stoves that were shown to be efficient under laboratory conditions have been found unsuitable in the field. There are very few biogas plants in operation, and the biogas programme can be said to have failed miserably.

2.4.5 Issues Emerging

In general, new and renewable energy technologies have the following characteristics: i) modular (i.e., suitable for small-scale applications); ii) high up-front capital costs; iii) intermittent in supplying energy; and iv) lack of dispatchability[5]. These characteristics make such systems less desirable in many cases, but more suitable in certain contexts. In places where the quantity of energy required and density of energy demand are low, then these systems may be more suitable than costly transmission and distribution lines. This is particularly true in mountain areas. However, the intermittent nature of the availability of solar and wind energy means that either expensive storage systems are required, or energy requirements can only be partially met so that additional investment is needed for back-up systems. The comparative advantage of most of these technologies is location specific, hence a blanket approach to technology dissemination tends to fail. At the same time, the lack of operation and maintenance services in mountain areas hampers the smooth functioning and performance of many renewable energy technologies (RETs). Each

[5] Dispatchability means easy to transport, handle, and store.

and every technology needs to be examined in terms of its suitability in a given place. This requires careful planning and implementation. Furthermore, mountain areas in general have diverse sociocultural practices, and each and every technology needs to be examined as to whether or not its use conflicts with the traditional practices and norms of the local communities.

The conventional approach is to make energy technologies available for consumers regardless of whether they suit local requirements. This approach has not been effective in the mountains, as not enough attention is paid to social, cultural, family, and religious practices. The felt needs of the mountain people are not taken into account, and target groups identified for technology interventions have not been provided with the proper information and training needed to run and operate the systems. In most cases, renewable energy technologies need operational skills at household or community level. For example, household level operational skills and acceptance are needed for improved cooking stoves, solar cookers, solar water heaters, and solar PV home systems. Community level skills and acceptance are required to make micro-hydro systems, community afforestation programmes, biomass gasifiers, or diesel generators functional.

2.5 An Overview of Energy Policies, Programmes and Institutions

The choice of energy policies and programmes in the countries of the HKH region are mostly dictated by the urban and industrial needs of the economy. They are designed to supplement and sustain economic productivity rather than to meet the social objectives of providing the energy required to meet the basic needs of the marginalised poor and to reduce drudgery, that of women and children. In addition, the issue of environmental sustainability has never been considered seriously while developing, procuring, and extracting energy. The energy policies, programmes, and institutions in each of the four selected countries of the HKH region are summarised below. This is followed by an overall summary of the issues identified.

2.5.1 China

Prior to the 1970s, issues related to conventional energy, such as production and allocation of coal, electricity, and oil, were managed according to the National Plan. Renewable energy programmes were still in the research and demonstration stage, apart from the establishment of a National Biogas Office in the central government to promote the biogas programme. From the 1980s, biomass, wind, geothermal, tidal, and solar energy were gradually introduced into the National Plan and were administered by several commissions and ministries. Many energy research institutions and academic organizations were established in the eighties. There are now a number of research institutions, academic societies, and professional industrial organizations under commissions and ministries.

The State Commission of Planning is responsible for the overall planning of the energy sector in China, with inputs from the provincial and county level offices of the Commission. The implementation of energy programmes is carried out by the line ministries (coal, electricity, water, petroleum, forestry, agriculture, nuclear) together with their provincial and county level offices. Scientific research is carried out by various institutions such as the Chinese Academy of Science, State Commission of Science and Technology, and State Commission of Education, together with their provincial and county level offices as well as through universities and colleges.

New and renewable energy technologies need to be appraised and permission granted by assigned institutions. These institutions are identified in each province by the government body. The implementation of rural energy programmes (primarily new and renewable technologies) falls primarily under the responsibility of the Ministry of Agriculture.

A systematic approach to energy planning has been introduced in China. The following steps are followed: a) investigation and study of the historical and current situations and establishment of an energy data base; b) formulation of energy plans to meet social and economic goals (includes forecast of demand, resource and technology appraisal, energy supply/demand balance, and identification of factors that influence energy policy decisions); and c) formulation of investment and budgetary plans.

The national policy for developing rural energy in China states that policies should be made according to local conditions with the exploitation of various forms of energy based on their availability at the local level to provide practical benefits to local communities. This statement has provided impetus for the development of renewable energy technologies in various parts of China wherever a strong manufacturing base exists.

2.5.2 India

The Planning Commission of India is responsible for energy planning and has carried out various studies and solicited recommendations from expert bodies. Notable among these are the Working Group on Energy Policy (1979) and the Advisory Board on Energy (1983-88). The earlier plans have tended to reflect more short and medium-term concerns than long-term policy imperatives.

During the Eighth Five Year Plan (1992-97), emphasis was placed on long-term integrated planning and particular attention paid to energy end use and the development of an efficient strategy for long-term energy supply. The energy strategy proposed for the future emphasised, as the highest priority, the sustainable development of energy that can fulfill the basic energy needs of the rural and urban poor. The strategy was also to ensure a gradual shift from non-renewable energy resources to renewable ones, with increasing emphasis on demand management, conservation, and efficiency.

The Ministry of Non-conventional Energy Sources (MNES) is mainly responsible for developing renewable energy plans and programmes, whereas state nodal agencies, such as the Himachal Pradesh Energy development Agency (HIMURJA), Arunachal Pradesh Energy development Agency (APEDA), and State Rural Works' departments, implement renewable energy programmes at the state level. Other governmental and non-governmental agencies are also involved in implementing these programmes. The national programmes on biogas development are looked after by the agricultural departments or state agro-industries' corporations, the improved cooking stove programme by the rural development departments, solar thermal and PV programmes by the state energy development agencies, and small hydropower programmes by the power departments or the state electricity boards. The improved cooking stove programme is being implemented by MNES through its nodal agencies and through social welfare departments of the state governments. Academic institutions and polytechnics provide technical and training support. Such support systems are actually common to many RET programmes.

The Eighth Five Year Plan specified the installation of renewable energy technologies (500-600MW) during the period of the plan. During the plan period, a new strategy and action plan was envisaged to increase the number of installations from 600 to 2,000MW through mobilisation of institutional financing and private sector investment, stimulated by entrepreneur development and a package of incentives. Major policy changes have been made to encourage market development, to minimise subsidies, and to reduce the existing price distortion between renewable and conventional energy sources. These policy changes will bring about major changes in terms of the energy mix in mountain areas where a vast potential, for renewable energy resources exists.

2.5.3 Nepal

The National Planning Commission is primarily responsible for developing energy policies, with a substantial input from the Water and Energy Commission Secretariat. Energy development policies as such were only formally introduced in Nepal from the Sixth Five Year Plan period (1980-1985). Prior to the Eighth Five Year Plan (1992-97), the policy was to develop energy resources in concert with the overall objectives of economic growth while preserving an ecological balance.

In the Eighth Five Year Plan, the energy sector received high priority. The following strategies were proposed: a) to maximise the development of indigenous energy resources; b) to promote cost effective and environmentally sensitive energy conservation and demand management practices; c) to devise appropriate mechanisms for financing hydropower projects through commercial sources, as well as encouraging other means of financing; d) to enter into energy import/export agreements keeping in mind the national interest; e) to formulate rational energy pricing so that it reflects the social costs without compromising overall national goals; f) to give authority to the respective ministries to solve the environmental problems associated with energy supply and demand; and g) to examine the possibility of transferring ownership of government-owned energy sector utilities to the private sector.

The Nepal Electricity Authority (NEA) under the Ministry of Water Resources is responsible for power generation, transmission, and distribution; while the Electricity Development Centre issues licences for both private entities and the NEA under the Electricity Act. The Nepal Oil Corporation and Nepal Coal Limited, under the Ministry of Supplies, are responsible for the import of petroleum fuels and coal respectively.

The Alternate Energy Promotion Centre (AEPC), a newly established institution under the Ministry of Science and Technology, is responsible for the development and promotion of new and renewable energy technologies. Other government-supported agencies, such as the Royal Academy for Science and Technology and the Research Centre for Applied Science and Technology, provide research and development support to the overall energy sector. Credit facilities to install RETs are provided by various banks; these include the Agricultural Development Bank (ADB/N) and the Rastriya Banijya Bank. The ADB/N plays a key role in promoting RETs in rural areas. Government subsidies are channelled through the banking system. Several private and non-government organizations are also involved in the development of RETs in Nepal.

2.5.4 Pakistan

National energy planning in Pakistan is the responsibility of the Energy Wing of the Ministry of Planning and Development, and energy plans are set within the framework of the national macro-economic development plan. Planning for conventional energy development is carried out by a number of ministries and public sector utilities, in particular the Ministry of Petroleum and Natural resources and the Ministry of Water and Power, the latter being responsible for the Water and Power Development Authority (WAPDA), the national power utility.

The Eighth Five Year Plan (1993-98) aims to explore and exploit domestic energy resources; improve and expand the transmission and distribution system for energy; rationalise energy prices in order to promote energy conservation and enable self-financing; and to decentralise and deregulate the energy sector in order to promote participation of the private sector. On the demand side, the central thrust is for energy conservation through incentives and pricing. Similarly, the main element in the supply policies is improvement of the pricing structure of fossil fuels to reflect the border prices. At the same time, the government has announced policy packages for promoting private sector investment in the development and promotion of indigenous oil, gas, and hydropower.

Energy development in mountain areas is dominated by the extension of grid electricity and petroleum product supplies to rural areas. The plan does not recognise the role of other sources of renewable energy (solar, wind, biogas, geothermal), and no special effort has been made to formulate energy plans for mountain areas as such.

WAPDA's Rural electrification Office is responsible for planning and implementing rural electrification programmes. The principal approach to rural electrification is grid extension. A Small Hydel Development Organization (SHYDO) was established in 1986 by the NWFP Government. The name of the organization has now been changed to Sarhad Hydel Development Organization (SHYDO), with a broader mandate to implement and execute large hydel schemes (<50MW) rather than small ones (<5MW).

The Director General's Office for New and Renewable energy resources (DGNRER) is reponsible for the programme on renewable energy technologies, but this office is at present non-functional. At present, the Pakistan Council for Appropriate Technology (PCAT) has the responsibility for disseminating fuel efficient cooking stoves and implementing of micro-hydro projects. Recently, a proposal was submitted by the Ministry of Science and Technology (MOST) to create a new Council for Renewable energy Technologies (CRET) by merging the PCAT, the National Institute for Silicon Technology (NIST), and the Solar Energy Centre of the Pakistan Council for Scientific and Industrial Research (PCSIR).

2.5.5 Issues Related to Energy Policy, Planning, and Institutions

In general, the underpricing of petroleum fuels has hampered the growth of new and renewable energy technologies. Underpricing of electricity during the eighties led to a rapid increase in demand which resulted in increasing reliance on thermal generation and, subsequently, high emissions of pollutants.

Policies for promoting forestry and energy development in the mountains were initially geared towards reducing the consumption of fuelwood with the intervention of imported cooking stoves. These interventions failed as a result of the absence of proper evaluation of the multiplicity of traditional technologies and the lack of regard for the sociocultural values of the mountain populations. At the same time, consumption of fuelwood was perceived as the main cause of deforestation. Other factors, such as collection of fodder for livestock, the need to use land for cultivation because of low productivity, and large-scale felling of timber, never received appropriate attention when designing energy technology options to suit local conditions. Furthermore, alleviation of human drudgery and improvement of deteriorating health conditions, particularly for women and children, and combatting decreasing soil fertility were never considered seriously.

Rural electrification always emphasised fulfilling the lighting loads of small towns and peripheral areas, rather than fulfilling the needs for motive power that could lead to economic transformation of the mountains into productive units. Electrification was considered to be a welfare package with the price of electricity always subsidised.

Energy planning investments were mostly biased in favour of large schemes, and emphasis was always placed on the expansion of supply rather than on the potential of energy demand management. There are no adequate policies to promote decentralised renewable energy systems and end-use appliances.

The most common factors responsible for the poor performance of the energy sector are government interference in the management of energy institutions, lack of trained manpower, overstaffing, lack of standardisation of equipment, limited planning, and a regulatory framework that discourages competition and the efficient allocation of resources. Interference in day-to-day management and pricing structures have been identified as critical institutional problems. Government interference is believed, in most cases, to have adversely affected least-cost investment decisions, resulting in inadequate management, weak planning, inefficient operation and maintenance, high losses, and poor financial monitoring control and revenue collection.

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Drum type biogas plant, Peshawar, Pakistan

Small hydropower plant near Leh, Ladakh, India

Agroprocessing unit operated by a micro-hydro power plant, Nepal

Chapter 3

Pattern of Energy Use in the HKH Region of China

by

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3.1 Introduction

3.1.1 Country Background

China lies in the east of Asia adjacent to the west coast of the Pacific. It has a total area of 9.6 million sq. km., of which 33.3 per cent is mountains, 26 per cent plateau, 12 per cent plains, 18.8 per cent river basin, and 19.9 per cent hills. There are 95 million hectares of cultivated land and 129 million hectares of forest (13.4% of the total area) (SBC 1995a; SBC 1996a).

At present (1995) the country is divided into 23 provinces, five autonomous regions, and three municipalities (directly under the central government). The total population is 1.21 billion, of which 0.35 billion (29%), live in cities and towns and 0.86 billion (71%) in rural areas. In 1995, the GNP was 5,728 billion RMB *yuan*, equivalent to approximately 690 billion US dollars, and the GNP per capita was 4,733 RMB *yuan* (SBC 1996a).

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When the People's Republic of China was founded in 1949, the production of energy was 703 million GJ. By 1953 it was 1,524 million GJ. In 1995 production was 38 billion GJ-75.5 per cent from coal, 16.7 per cent from crude oil, six per cent from hydro-electricity, and 1.8 per cent from natural gas. The annual production of coal is 1.36 billion tonnes, the highest in the world; that of crude oil 150 million tonnes, sixth in the world; of electricity, 1,007 billion kWh, the fourth in the world; and of natural gas, 17 billion cu. m. (MOE 1997).

3.1.2 The Hindu Kush-Himalayan Region of China

The HKH region of China lies in the southwest of the country. The total area of the region is 1.6 million sq. km. The total cultivated land is 2,795,200 hectares, of which 1,864,000 hectares are in Sichuan Province, 708,667 hectares in Yunnan Province, and 222,260 hectares in the Xizang (Tibetan) Autonomous Region. The total population of the HKH region is 19 7 million and includes people from more than twenty different nationalities. People from minority nationalities form 95 per cent of the population in the Xizang Autonomous Region, 15 per cent in Sichuan Province, and 35 per cent in Yunnan Province (SBS 1995 & 1996; SBX 1995 & 1996; SBY 1995 & 1996). The HKH region of China is sparsely populated. Most of it is covered by mountains, plateaus, and gorges. Eighty per cent of the total area is situated at more than 3,000 masl.

The HKH region can be divided geographically into four parts, the north of Xizang Autonomous Region, the south and east of Xizang Autonomous Region, the west of Sichuan, and the west of Yunnan. The average temperatures are -20°C ~22°C in the Xizang Autonomous Region, -9°C ~26°C in Sichuan Province, and 0°C ~26°C in Yunnan Province. These temperature figures are lowest and highest during the year. The annual precipitation lies between 60 and 1,000mm in the Tibetan Autonomous Region, between 500 and 1,200mm in Sichuan Province, and between 600 and 2,300mm in Yunnan Province. The north of the Tibetan Autonomous Region (the Zangbei Plateau) is quite dry and its average annual precipitation is less than 200mm. The south and east of the Tibetan Autonomous Region are wetter than the north with an average annual precipitation of 700mm (SBS 1996; SBX 1996; SBY 1996). The HKH region is rich in water resources, with many rivers such as the Yaluzangbu, Lancang, Jinsha, and Nu rivers. There are also coal resources, and the geothermal resources in the region are considered the best in China. Box 3.1 describes the condition of the natural resources in the region.

The transport facilities in the region are not very convenient because of the complex topography, although there are highways between Sichuan and the Tibetan Autonomous Region, Yunnan and the Tibetan Autonomous Region, and Sichuan and Yunnan. Most industries are of the micro-enterprise type processing the locally available resources.

Box 3.1: The Condition of Natural Resources in the HKH Region of China

The Tibetan Autonomous Region (Tibet)

Hydropower	There are many lakes and rivers in Tibet. The hydropower potential is about 200,000 MW. The Yaluzangbu River alone has a potential of 80,000 MW.
Geothermal	Geothermal resources are plentiful, there are 600 geothermal spots. Twenty-two per cent have a temperature higher than 80 °C, 26% a temperature between 60 and 80°C, 35% a temperature between 40 and 60 °C, and 17% a temperature lower than 40 °C.
Minerals	Mineral resources are plentiful. The reserves of 11 different kinds of minerals (ferro-chrome, lithium, copper, boron, magnesite, barite, arsenic, muscovite (white mica), gypsum, pottery clay, and peat) rank among the first five most plentiful sources in the country.

The HKH Region of Sichuan Province

Hydropower	The Yangtze, Min, Tuo, Jialing, and Longxi rivers are all suitable for building cascade hydroelectric power plants. The total potential hydropower in the region is 50,000 MW (1/3 of the potential in the province).
Forests	There are 11.53 million hectares of forest in the province, half of which lie within the HKH region.
Grasslands	There are 14.23 million hectares of exploitable grasslands in the province, one-third of which lies within the HKH region.
Minerals	There are no reserves of coal, iron, copper, or manganese in the HKH area of the province, but the remainder of the province is rich in these resources (reserves of 6,532 million tonnes of coal, 3,564 million tonnes of iron, and 35 million tonnes of manganese).

The HKH Region of Yunnan Province

Hydropower	The potential hydropower is 52,000 MW (half of the total potential in the province).
Geothermal	The Tengchong volcano group in the HKH region is one of the biggest volcano groups in China. There are dozens of volcano cones and nearly a hundred thermal springs and steam springs.
Forests	There are 9.533 million hectares of forest in the province, one-third of which falls within the HKH region.
Minerals	There are no reserves of coal or iron within the HKH area of the province, but the remainder of the province is rich in these resources (reserves of 1,176 million tonnes of iron and 23,927 million tonnes of coal).

Sources: SBS 1995 & 1996; SBX 1995 & 1996; SBY 1995 & 1996

The socioeconomic conditions are poor as a result of the low level of physical and social infrastructure. The GDP per capita in the HKH region of China is approximately half that in China overall (Table 3.1).

Table 3.1: Living Standards in the HKH Region of China, 1995

Units: In RMB Yuan

Description	GDP per Capita	Income per Capita		Consumption per Capita	
		In Cities	In Rural Areas	In Cities	In Rural Areas
China	4810	4288.1	1577.7	5044.0	1479.0
Sichuan	2516	4004.8	1158.3	2895.0	947.0
Yunnan	1553	4113.2	1010.9	3195.0	933.0
Xizang	1984		1200.3	3700.0	694.0

GDP = Gross Domestic Product

Sources: SBC 1996a; SBS 1996; SBX 1996; SBY 1996.

3.1.3 The Energy Situation in the HKH Region of China

Energy plays an important role in the national economy in the realisation of modernisation, since it is related to the growth of national productivity and improvements in living standards. There are plentiful energy resources in the HKH region of China and, as the region is sparsely populated, the energy resources available per capita are much higher than the national average. Exploitation of these energy resources, however, is very limited as a result of the lack of convenient transport facilities, low level of human resource development, and prevailing low economic base of the region. In practice, usable forms of energy for industrial and agricultural activities and to meet daily household needs are in short supply. The main problems are shortage of energy supply, low-efficiency of utilisation, and poor management. In rural areas particularly, farmers and herdsmen use biomass fuels that can be obtained locally. The overexploitation of biomass fuel is a visible phenomenon, as there are no other suitable and affordable forms of energy available to meet household needs. This has resulted in over-cutting of standing forest biomass aggravating soil erosion, soil desertification, and a dry climate. These effects threaten the sustainable development of agriculture and destroy the environment and ecology of the area.

The Chinese government has paid attention to improving the national energy supply situation, with special emphasis on the HKH region. Detailed field investigations have been carried out to evaluate available energy resources, to understand the present level of energy consumption, to formulate long-term energy plans, and to design investment packages at state and local levels for the implementation of energy programmes. The guiding principle in the formulation of these plans and investment packages is to suit local conditions. Institutional arrangements and management systems have already been established at various levels from central to local government. The gaps between energy supplies and demand have been reduced in the last decade with the aim of promoting the development of the economy and improving the living standards of the population. The energy sector has attracted the attention of the United Nations, relevant international organizations, and the governments of many developed countries within the region, and many joint projects have been carried out. International and domestic cooperation will lead to further improvements in the energy-related infrastructure so as to contribute towards the economic development of the region.

In the HKH region of China, energy is consumed primarily in the production of goods and materials and in fulfilling the household energy demand. The present energy consumption pattern in the region is quite complex as it is related to economic and social factors. Energy consumption is classified into direct consumption and indirect consumption. For example, direct consumption of energy in agricultural production includes energy for tilling, threshing, harvesting (tractors, agricultural machinery, and animal power), irrigation and drainage, grain and cotton processing, and transportation. Indirect consumption of energy in agriculture includes the energy for producing chemical fertilizers, pesticides, agricultural plastic film, agricultural machinery, agricultural vehicles, and other agricultural materials and implements.

The organization of energy statistics is a complicated task. The commercial energy consumption figures are recorded by special agencies, but data for non-commercial energy consumption are difficult to get as energy is normally obtained and consumed locally. There are no special agencies to collect this type of information. Therefore, the energy administration departments estimate or calculate the non-commercial energy related data needed for the analysis of energy supply and demand, and these estimates are considered sufficient for planning and implementing energy-related programmes within the HKH region.

3.2 The Energy Resource Base

There is an abundance of energy resources in the region. The energy resource base includes both traditional and commercial energy. Traditional energy categories include fuelwood, agricultural straw, and animal dung; while commercial fuels include coal, natural gas, petroleum fuels, electricity, and geothermal energy. Besides these, there is a huge potential for renewable energy using small hydropower and solar resources.

3.2.1 Traditional Energy

The HKH region of China is mainly covered by plateaus and mountains, and most of the population are farmers and herdsmen. The availability of forest resources is high (1.2 ha per capita), but, because of the inconvenience of transportation, people tend to use the fuelwood available locally. This has resulted in over-cutting of nearby forest resources. Stoves used are low in efficiency, and the supply of fuelwood from forest areas close to a settlement cannot meet the demand. The fuelwood available on a sustainable basis from accessible forest areas meets only about 35 per cent of the total demand. The species of trees identified as suitable for fuelwood production in the region are Rhus Typhina Lin, Pinus Massoniana Lamb, Zinea insignnis, Acacia Mearnsii, Acacia dealbata, Alnus cremastogyne burk, Amorpha fruticosa L, and Robinia preudoacacia (MOF 1990; MOF 1992).

There are 1,180kg of agricultural straw available per capita in the HKH region (the thermal value of straw is 14,630 kJ/kg). Straw is used as energy mainly in rural and backward areas. The efficiency of the normal stoves used for burning straw is only 10-15 per cent. The value increases to 25-30 per cent when efficient stoves are used (MOA 1992; MOA 1995b). The methods of using straw as fuel are (a) direct combustion — very simple and easy and the most widely used method; (b) production of a suitable fuel such as alcohol or biogas — this method is employed in the HKH regions of Sichuan and Yunnan provinces (only 1% of the straw is used in this way); and c) production of gas through biomass pyrolysis — this technique is not used in the region.

Livestock manure is a kind of organic waste, and an important resource for promoting a good cycle of agricultural development. The rational way to use livestock manure is to return it to the field. An even better method is to make biogas, a high-quality fuel, through anaerobic fermentation and to make organic fertilizer from the solid and liquid residues left after fermentation.

There are 2,221kg of animal dung available per capita within the HKH region, with an average thermal value of 12,824 kJ/kg. Five hundredkg of oxen or cattle produce 28-36kg of wet manure per day, and a 500kg horse produces 28kg of wet manure per day (MOA 1994; MOA 1995b). Household biogas digesters have become popular in the HKH regions of Yunnan and Sichuan. These units are used for eight to 10 months a year to meet cooking and lighting requirements. The technology is not suitable in Tibet because of the harsh climatic conditions. Farmers and herdsmen in Tibet burn dried livestock manure directly for cooking purposes.

3.2.2 Commercial Energy

There are considerable reserves of fossil fuels in the provinces around the HKH region (Table 3.2), particularly coal in Sichuan and Yunnan Provinces (SBS 1996), but exploitation of these resources is nominal (Table 3.3). There are more than 96 million tonnes of proven reserves of coal in Sichuan Province. Coal production in

Table 3.2: Energy Reserves in the Provinces of the HKH Region of China in 1995

Description	Coal (bT)	Crude Oil (mT)	Natural Gas (bm^3)	Electricity (bkWh)	Hydro-electricity (bkWh)
China	1.361	150.05	17.95	1007.73	190.58
Sichuan	0.096	0.17	7.66	57.60	25.98
Yunnan	0.028	0.10	22.84	16.21	n.a.
Tibet	n.a.	0.48	0.30	n.a.	n.a.

Sources: SBC 1996a; SBS 1996; SBX 1996; SBY 1996
check use of billion, T, m^3
bT - billion tonnes; mT - million tonnes; and b - billion

Table 3.3: Exploited Energy Resources in the Tibetan Autonomous Region, Sichuan Province and Yunnan Province

Description	Tibet	Sichuan	Yunnan
Electricity thousand GWh	0.64	27.88	27.03
Hydroelectricity	0.34	3.12	1.47
Thermal electricity	0.30	24.76	25.56
Coal (million tonnes)	0.03	68.36	42.04
Fuelwood (million tonnes)	1.40	2.51	27.28
Hydropower (million kW)	200	50	50
Solar energy (kc/cm²·year)	180–220	120–150	120–150
Agricultural residues ('000 tonnes)	85.7	101.3	122.1
Livestock manure (billion tonnes)	11.63	12.44	21.75
Geothermal spots	> 600	> 60	> 100

Sources: SBC 1996a; SBS 1996; SBX 1996; SBY 1996

the Tibetan autonomous region is very limited, only 30,000 tonnes in 1995 (MOST 1995). Small coal mines exploit small-scale coal resources, but the production of coal from small mines is not steady because of poor management, low technological and production efficiency and old equipment. There are 10 small coal mines in the HKH region out of 80,000 in China. Almost 50 per cent of the coal produced from small mines is used by industry, the rest in the household sector in rural areas.

The HKH region is one of the areas of China richest in geothermal resources. Tengchong in Yunnan Province and Yangbajing in the Tibetan Autonomous Region in particular have high temperature geothermal spots. It is estimated that the geothermal resources in China up to 3,000 metres below ground are equal to 3.2123×10^6MW (MOMG 1993). The Yangbajing Geothermal Power Plant has been operating for more than 10 years. It has an installed capacity of 25,000kW and is the biggest geothermal plant in China. It supplies 45-60 per cent of the electricity consumption in Lhasa. Waste water from the power plant is used to irrigate vegetables grown inside greenhouses. Several technologies related to the utilisation of geothermal energy are being developed (plantation, fish farming, poultry incubation, drying agricultural products) and many are ready for dissemination.

3.2.3 Renewable Energy

According to Chinese regulations, small hydropower plants can only be built on middle and small rivers, and the total installed capacity should be less than 25,000kW, with a unit capacity not exceeding 6,000kW. The small hydropower potential in China is 70 million kW, of which 20 million kW is already exploited (MOA 1995a; MOA 1995b). The potential small hydropower available within the HKH region has not been exploited as much as in other regions of China because of the lack of investment resulting from the poor economic situation of the region.

The HKH region of China is highly suitable for the exploitation of solar energy resources. The solar radiation intensity is 500-690 kJ per cm^2 per year in Sichuan and Yunnan Provinces and 830 kJ per cm^2 per year in the Tibetan Autonomous Region (CAAERP 1988).

3.3 Energy Consumption Pattern

Table 3.4 shows the final energy consumption pattern in the HKH region of China. If a comparison between the energy consumption pattern in the HKH region of China (Table 3.4) and the country as a whole is made, the following pattern can be seen a) the annual per capita final energy consumption in the HKH region is comparable with the national average (43.1 GJ compared to 40.6 GJ); b) the HKH region is more dependent on biomass fuels (65% compared to 22% of total energy); c) in the HKH region the household sector consumes more than 60 per cent of the total final energy and in China it is less than 25 per cent; and d) coal is the major commercial fuel in both the HKH region and China (contributing 38% of total energy in the HKH region and 63 per cent of total energy in China). The pattern of energy consumption in the HKH region reflects the poor supply infrastructure for commercial energy, the lack of purchasing power in the region, and the low level of industrial development and transport infrastructure.

Table 3.4: Final Energy Consumption Pattern in the HKH Region of China, FY 1994/95

Description	Biomass		Commercial Fuels		Total Energy	
	'000 GJ	Per cent	'000 GJ	Per cent	'000 GJ	Per cent
By Sector						
Household	344,201	79	184,828	45	529,072	62
Commercial/Institutional	33,970	8	53,475	13	87,462	10
Industrial	54,902	13	147,761	36	207,141	24
Agricultural	0	0	3,676	< 1	3,677	< 1
Transport	0	0	23,956	6	23,956	3
Total	443,073	100	413,697	100	851,308	100
Total Population (in thousands)					19,700	

Source: Study estimates

The industrial sector in the HKH region still consumes 13 per cent of total energy in the form of biomass fuels, but the agricultural sector is dependent primarily on commercial fuels if the contribution of animate energy is not taken into account.

3.3.1 Biomass Energy Use Pattern

The annual per capita consumption of fuelwood in the HKH region of China is 760kg (Table 3.5), that of agricultural residues 460kg, and of animal dung 321kg. This amounts to a total per capita consumption of biomass fuels of the equivalent of 1,316kg of fuelwood, compared to a national average consumption of 590kg. The prevailing pattern of consumption has the following features: a) fuelwood is still the main source of energy in the household sector. Table 3.5 shows that more than 50 per cent is fuelwood, presumably because it can be collected from the nearby woods in most rural areas and is also 'free'; b) biomass fuels still contribute 13 per cent of the total energy requirement of the industrial sector, indicating the prevalence of cottage industry activities and the low level of modern industrial growth in the region; and c) agricultural residues and animal dung contribute about 42 per cent of the total biomass supply, indicating the low availability of fuelwood and the prevalence of an agro-pastoral farming system.

Table 3.5: Biomass Energy Consumption Pattern in the HKH Region of China

Description	Fuelwood		Agricultural Residues		Animal Dung	
	kg per capita	Per cent	kg per capita	Per cent	kg per capita	Per cent
By Sector						
Households	612	81	350	76	261	81
Commercial/Institutional	41	5	30	7	60	19
Industrial	107	14	79	17	0	0
Total	760	100	460	100	321	100

Source: Study estimates

3.3.2 Pattern of Commercial Energy Use

The annual per capita consumption of commercial fuels in the HKH region of China is 21,000 MJ (compared to a national average of 33,361 in Table 1.4), of which 78 per cent is met by coal, 11 per cent by electricity, nine per cent by petroleum fuels, and two per cent by natural gas. Of the total commercial fuels about 45 per cent is consumed in the household sector, 36 per cent by the industrial sector, 13 per cent by the commercial sector, and less than one per cent by the agricultural sector (Table 3.6). The household sector depends primarily on coal (80%) and electricity (12%) among commercial fuels. This is true for all sectors except the transport sector which depends primarily on petroleum fuels (51%) and electricity (36%), with coal contributing only about four per cent.

Table 3.6: Commercial Energy Consumption Patterns in the HKH Region of China

Description	Coal and Coke		Petroleum Fuels		Natural Gas		Electricity		Total Commercial	
	MJ per Capita	Per cent	MJ per Capita	Per cent	MJ per Capita	Per cent	MJ per Capita	Per cent	MJ per Capita	Per cent
By Sector										
Household	7,501	46	675	34	76	18	1,131	50	9,382	45
Comm/Institutional	2,394	15	188	9	60	15	73	3	2,714	13
Industrial	6,243	38	490	25	157	38	611	27	7,501	36
Agricultural	155	1	12	< 1	4	1	15	< 1	187	< 1
Transport	45	< 1	616	31	114	28	441	19	1,216	6
Total	16,337	100	16,337	100	410	100	2,271	100	21,000	100

Source: Study estimates

3.4 Status of Renewable Energy Technologies

In China, there are standards for all the kinds of energy technologies being marketed and promoted in rural areas, including conventional energy technologies, new energy technologies, and renewable energy technologies. Energy technologies and products cannot be disseminated anywhere in China unless appraised by assigned national administration departments. There are a number of renewable energy technologies in operation in the HKH region of China, although the number of units is not impressive compared to the rest of the country (Table 3.7).

Efficient Biomass Stoves: There are more than 1.5 million efficient biomass stoves within the HKH region. These stoves can burn any type of biomass fuel with a pot utilisation efficiency of 25-30 per cent, compared with an efficiency of about 10-15 per cent for traditional stoves (MOA 1995b).

Table 3.7: Installation of Renewable Energy Technologies in China

Description	Unit	HKH region of China	China total
Family-size Biogas Plants	'000 units	83	5,400
Improved Cookstoves	'000 units	1,541	158,000
Solar Thermal Systems	sq. m.	111	n.a.
Solar Cookers	'000 units	60	n.a.
Solar Greenhouses	'000 sq. m.	15	n.a.
Solar Houses	'000 sq. m.	120	n.a.
Solar Lamps (7-9 Watts)	kW	800	n.a.
PV Systems	kWp	105	n.a.
Wind Turbines (100-200 watts)	kWp	n.a.	234
Micro-hydropower	MW	< 2	600
Small Hydropower	MW	n.a.	15,760

Sources: MOA 1996; MOE 1997.

Biogas Technology: The first biogas digester developed in China was built in 1920 for lighting. Biogas technology developed rapidly after the 1970s and by the end of 1995 there were 5.4 million biogas digesters operating in China, of which 83,000 are installed within the HKH region. Large-scale biogas plants have been established in areas with large amounts of raw materials since the1980s. By the end of 1995, there were 600 large-scale biogas plants in China (MOST 1992; MOA 1995b), but none of these are in the HKH region.

Small and Micro-hydropower Plants: The first small hydropower plant in China was built in Yunnan Province in 1912, with an installed capacity of 2 x 240kW. By the end of 1949 there were 33 hydropower plants in the country with a capacity of less than 500kW. In the 1970s, the total installed capacity of small hydropower plants was 12,000kW, some connected to the main grid and some to the local grid network, supplying electricity with a voltage of 35 kV. By the end of 1995, there were small hydropower plants in 1,567 counties and the total installed capacity was 15.76 million kW, with generated electricity of 50.8 billion kWh per annum, accounting for 33 per cent of the total hydroelectricity generated. The installed capacity of micro-hydropower plants in the HKH region of China is about 1.69MW (CAAERP 1995a; CAAERP 1995b; MOA 1995b).

Solar Energy Technologies: Thermal utilisation and photovoltaic conversion are the principal ways of using solar energy in the region. The solar technologies so far installed include: 111,288 sq.m. of solar thermal systems; 60,000 solar cookers; 14,900 sq.m. of greenhouses; 120,00 sq.m. of passive solar buildings; 800kW equivalent of solar lamps, each with seven to nine watts capacity; and 105kWp of PV systems.

3.5 Production Capability of Renewable Energy Technologies

There are 79 factories manufacturing hydropower equipment in China, of which 17 are located in Sichuan and Yunnan provinces. There is no manufacturing capability in Tibet (Box 3.2). There are 9,867 biogas dissemination institutions and 30,895 biogas technicians in China. The county and rural energy offices undertake distribution of household biogas digesters. There are many institutions able to design large-scale biogas plants, including the Chinese Academy of Agricultural Engineering Research and Planning, the Chengdu Biogas Institute, the Hangzhou Energy Engineering Corporation, and the Henan Provincial Design Academy. There are 12 institutions involved in designing solar houses and greenhouses. There are 300 manufacturers producing solar water heaters, in addition to seven service institutions involved in research and development of solar water heaters and five institutions in solar cooker development. There are seven manufacturers of solar photovoltaic cells and four service institutions involved in product development and

Box 3.2: Number of Institutions in China Involved in the Development of Renewable Energy Technologies

Type of Technology	No. of Manufacturers	No. of Service Institutions	Remarks
1. Small, Micro-hydropower	82	State and County-level Bureaus of Hydropower	These institutions are classified in four grades based on their design capability: Grades A & B >2,500 kW; Grade C < 2500 kW; Grade D < 500 kW.
2. Biogas Plants	9,876	8	Primarily County & Rural Energy Offices
3. Solar Building Technologies/ Solar Greenhouses		5	Primarily Research Institutions
4. Solar Cookers	2	3	Tibet is the most suitable area
5. Solar Photovoltaic Systems	N.A.	4	Installation of Solar PV is at the demonstration phase
6. Wind Power Machines	3	4	Small-scale, 100-200 W, and medium-scale, 50-120 kW, are becoming popular in Mongolia
7. Fuelwood Saving Stoves	N.A.	3	Products are available in the market

Sources: MOST 1991; MOA 1992; MOA 1994; MOA 1996; CAAERP 1995b

research. There are seven service institutions involved in wind technology development (MOA 1992; MOA 1994: CAAERP 1995b; MOA 1996).

3.6 Energy Planning and Programme Implementation

There are several commissions and ministries that administer the energy sector in China. Each of them has different responsibilities and functions. These commissions and ministries have branches in provincial and county level governments. Box 3.3 shows the relationship between the various state and county-level commissions and the various line departments under different ministries, together with their responsibilities and functions.

Prior to the 1970s, the production and allocation of conventional energies such as coal, electricity, and oil were managed according to the Chinese Government's national plan. At that time renewable energy technologies were at a research and small-scale demonstration stage, except for the government National Biogas programme. From the 1980s, biomass energy, wind energy, geothermal energy, and tidal energy were gradually included in the national plan and were administered by the relevant commissions and ministries, as shown in Box 3.3. Later, research and academic institutions were established with the responsibility for research, development, and dissemination of renewable energy technologies. These institutions are under different commissions and ministries. Academic societies and professional industrial organizations were also established under the commissions and ministries.

Box 3.3: Arrangement of Energy Departments in China

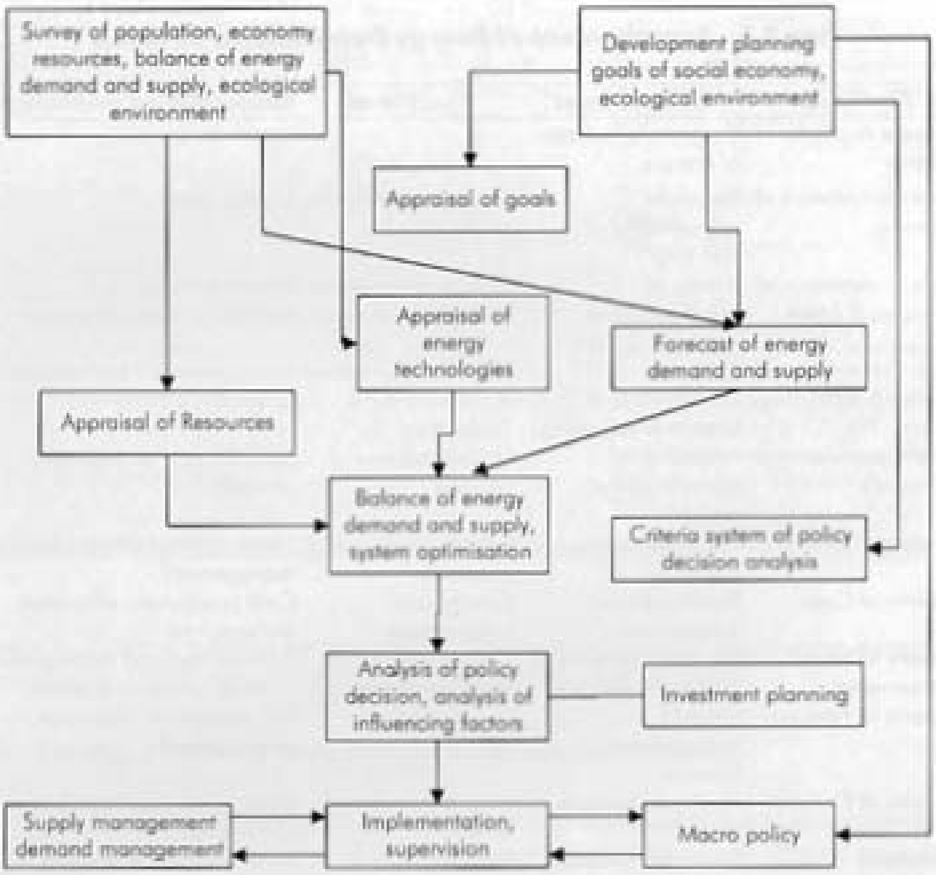
First level	Second level	Third level	Responsibility and function
Chinese Academy of Science	Provincial academies of science		
State Commission of planning	Provincial commissions of planning	County commissions of planning	Making plans
State Commission of Economy & Trade	Provincial commissions of economy & trade	County commissions of economy & trade	Project management, technology industrialisation
State Commission of science & technology	Provincial commissions of science & technology	County commissions of Science & Technology	Management of key research projects
State Commission of Education	Provincial commissions of education	Universities and colleges	Scientific and technological research
Ministry of Electricity	Provincial bureaus of electricity	County bureaus of electricity	Electricity production, allocation, management
Ministry of Coal	Provincial coal corporations	County coal corporations	Coal production, allocation, management
Ministry of Water Conservancy	Provincial bureaus of water conservancy	County bureaus of water conservancy	Construction and management of small hydropower plants
Ministry of Petroleum	Oil field management bureaus		Oil production, allocation, management
Ministry of Forestry	Provincial bureaus of forestry	County bureaus of forestry	Development and management of fuelwood
Ministry of Agriculture	Provincial offices of rural energy	County offices of rural energy	Rural energy construction
Ministry of Nuclear Industry	Corporations directly under the Ministry		Construction of nuclear power plants

Sources: MOF 1992; MOST 1992; MOST 1995; MOE 1997

The State Commission of Planning is responsible for the overall planning of the energy sector in China, with inputs from provincial and county level offices of the Commission. Energy demand and supply analysis plays an important role in the formulation of energy plans and policies. Box 3.4 shows the structure of energy planning in China.

Energy demand analysis is carried out using econometric techniques. This entails estimation of the relationship between changes in energy demand and changes in predictable economic variables and other factors. These relationships are exam-

Box 3.4: Structure of Energy Planning



ined in terms of policy interventions and technological improvements. Factors that influence the energy demand in particular regions include population, living standard, structure of the economy, level of technological advancement, resource availability, prices, and type and functional capability of institutions. At present, an elastic coefficient method and an activity analysis method are used for energy demand analysis.

At the same time, energy supply analysis is performed in order to evaluate the potential energy supply and the relevant energy supply programmes. It is essential to understand the energy supply system and its characteristics. Energy resources available in their natural form have to be extracted, processed, and converted with the aid of technologies prior to their use. Thus information on energy resources and technologies is vital. Energy resource information includes reserves, possible production rate, exploitation cost, and production constraints. Technology related information includes all the kinds of technology used in the energy supply system together with their characteristics such as life, efficiency, and cost. The energy supply analysis includes the following steps: a) appraisal of energy resources, supply potential, and conversion technology; b) analysis of the energy supply system and energy structure; c) identification of supply differences at each energy conversion phase; d) examination of possibilities for import and export between regions; e) analysis of energy prices; and f) appraisal of new and renewable energy technologies.

3.7 Environmental Impacts of Energy Use

The production, transformation, transportation, and consumption of energy will result in environmental pollution to a varying nature and degree. The main causes of environmental pollution and their treatment are shown in Table 3.8. At present, energy production and use in China face three main environmental problems.

Table 3.8: Principal Causes of Environmental Pollution and Their Treatment, 1995

Description	China	Sichuan	Yunnan	Xizang
Industrial waste water (million tons)	22189	1915.93	489.37	21.55
Treated industrial waste water (million tons)	21566	1151.62	438.28	0.47
Treated industrial waste water meeting standards (million tons)	4814	243.44	70.60	
SO_2 dispersal (million tons)	16.91	2.23	0.36	
Soot dispersal (million tons)	14.78	1.38	0.28	
Industrial waste gas (billion cu.m.)	10748	635.90	167.4	0.90
Industrial solid wastes, production (million tons)	645	42.90	24.47	
Industrial solid wastes, utilised (million tons)	285	17.80	5.02	
Industrial solid wastes, treated (million tons)	147	6.03	2.57	
Industrial solid wastes, disposed of (million tons)	22.42	3.99	5.16	

Sources: MOST 1992b; MOST 1993; MOES 1995

- At present, coal is the main contributor of energy. This results in a large number of detrimental environmental effects — including atmospheric pollution. In 1989, 13.6 million tonnes of smoke and dust and 14.8 million tonnes of SO_2 were dispersed in the atmosphere from coal burning, accounting for 62 per cent and 93 per cent of the total dispersed amount, respectively.
- The efficiency of energy conversion and use is low. The low efficiency of biomass utilisation results in pressure on natural forest and diversion of agricultural residues and animal dung from the field to the fire. The conversion efficiency of coal from its primary energy form into a secondary energy form is still very low in the production phase. The energy consumption per unit of industrial production is very high compared to that in developed countries, indicating inefficient use of energy. This situation is made worse by the application of low-technology, energy end-use equipment.

- A large amount of biomass energy is consumed in the rural area of China, and this has a negative effect on the environment. Nearly half of the energy consumed in rural areas is from biomass. Using biomass as a fuel destroys the ecology, causes soil erosion, and decreases land productivity.

In the HKH region of China direct burning of coal by households leads to atmospheric pollution. Industrial pollution is minimal as there are few industrial establishments within the region, except in some urban areas. The main environmental problem related to energy is the low efficiency of biomass energy use (MOF 1992). Most households and micro-enterprises use fuelwood, straw, and animal dung as their main fuel, so that these are extracted beyond their regenerative capacity. This results in forest destruction and soil erosion.

3.8 Main Findings and Conclusions

Energy is essential for social and economic development and the improvement of living standards. In the HKH region of China, as in the rest of the country, the energy sector is facing problems as a result of the increase in demand for energy to sustain rapid economic growth. The high level of energy consumption has increased environmental pollution. There is an imbalance between the supply potential of energy resources and their exploitation. Energy development in the region cannot depend on national support alone, but it cannot be separated from the national plan either. The only way to solve the energy problem in the region is to integrate the development aspirations of the region into the national plan.

Coal is the main energy resource in China, accounting for 75 per cent of the total energy consumption. The contribution of clean and renewable energy resources is nominal. Exploitation, processing, storage, and transportation of coal itself consume a lot of energy and produce large amounts of pollution. In the HKH region, the cost of these processes is higher than the national average, and the level of utilisation is much lower, reducing the economic viability of coal production. The development, utilisation, and management of renewable energy technologies are weak. Energy utilisation efficiency is poor, and consumption per capita is low. Energy shortage and wastage coexist.

If there is no change in the trend of energy development and consumption patterns, it will not be possible to meet energy demands taking into account resources, funds, transportation, and environmental protection, especially within the HKH region. Both energy production techniques and the consumption pattern must change. This can be achieved by diversifying the energy production structure and establishing pollution-free energy systems. This approach should form an integral part of a sustainable energy development strategy for the HKH region of China.

Strategies for the development of the energy sector in the HKH region should be aimed at inducing a structural change in the energy supply by reducing the supply of coal, by supporting major efforts towards hydropower development, by developing new technologies for energy utilization and renewable energy sources based on technological improvement and local conditions, by improving energy efficiency, by strengthening efforts in environmental protection, and by promoting the rational use of energy.

3.8.1 Planning and Management of Integrated Energy Development

There is a need to plan and manage energy in an integrated manner and to formulate and implement policies to suit a market-oriented economy. National economic development strategies should make energy development and environmental protection in the HKH region a priority. Attention should be paid to developing and disseminating pollution-free energy technologies. Energy related laws and regulations formulated by the Chinese government are also suitable for the HKH region of China and should be implemented.

The energy policy should aim at: a) strengthening energy management by improving the energy supply structure and energy distribution, increasing the proportion of clean and quality energy, and carrying out industrial reform with the objective of reducing energy consumption per unit production value; and b) strengthening the rural energy supply infrastructure, including electrification, and gradually changing the situation of ecological environmental deterioration caused by biomass overconsumption. A 20-year energy development plan with five-year implementation plans needs to be formulated for the HKH region. This plan should take into consideration the national economic development plan and environmental protection activities. Planning department should organize and coordinate plan formulation activities in conjunction with other departments such as those for economy, technology, agriculture, forests, energy, and finance. Emphasis should be given to developing energy laws and regulations suitable for the HKH region of China based on the national laws and regulations.

3.8.2 Improvement in Energy Efficiency and Energy Saving

There is a need to improve energy use efficiency and promote the rational use of energy resources so that environmental pollution can be reduced, sustainable development through social and economic development can be realised, and the energy supply and demand gaps within the HKH region can be closed. There is also a need to improve the quality of energy services within the HKH region in order to improve living standards. At present, the average energy use efficiency in China is about 30 per cent, whereas it is less in the HKH region. This indicates a substantial potential for direct energy saving. Overall the pattern of energy use in the industrial sector is not efficient in China, and that in the HKH region is worse. The proportion of high-energy consuming industries is large, but this situation can be changed if the industrial structure and product structure are adjusted and optimised. This indicates a potential for indirect energy saving.

Orientation of the Chinese economy towards a market-oriented economy would mean that existing policies, regulations, and management systems for energy saving will not be suitable. Therefore, it is desirable to formulate new laws and regulations for energy saving and to introduce new management systems suitable for a market-oriented economy.

Improvements in energy efficiency in the HKH region of China can be achieved by establishing and improving management procedures and approval systems that focus on energy saving, as well as formulating relevant policies and regulations. It should be possible to achieve an improvement in energy saving of two per cent by the end of 2000, and thus meet 50 per cent of the increase in energy demand through energy saving. This can be achieved by including energy saving activities in national economic and social development programmes, by establishing a special institution for energy saving management which will be responsible for identifying saving goals and implementation methods, formulating energy saving plans and policies, and organizing implementation of energy saving projects.

There is also a need to adjust energy prices and government subsidies so that energy prices reflect the 'true' economic cost. The following activities can increase energy savings: a) development and dissemination of advanced energy saving technologies; b) technological improvement of power plant and industrial furnaces and improving the efficiency of end-use devices; c) providing preferential taxes and loans for energy saving projects; d) formulating norms and standards for energy consumption in order to realise energy saving potential; e) strengthening education and propaganda on energy savings in order to improve awareness of energy saving in enterprises; and f) improving communication between the countries of the region and beyond to enhance international cooperation in the field of energy saving.

3.8.3 Development and Utilisation of New Energy and Renewable Energy

Renewable energy resources can be considered infinite and are mostly less polluting than fossil fuels. Therefore, development and use of new and renewable energy should receive a high priority. Renewable energy technologies that can be disseminated within the HKH region of China include large, small, and micro-hydropower plants; biomass gasification and liquefaction and briquette technologies; solar photovoltaic and thermal technologies; wind power and wind pump technologies; geothermal power plants; and thermal-gradient use technologies.

The objective of developing new and renewable energy in the HKH region is to increase the share of renewable energy in the energy supply mix. Targets by the end of the year 2000 should be an increase of 300MW in the installed capacity of hydropower plants; an increase in utilisation of solar energy by 1.5 million GJ; an increase in utilisation of geothermal energy by 1.5 million GJ; and an increase in thermal efficiency of biomass energy use by 10 per cent.

The following activities are envisaged as appropriate for the HKH region of China. These are: a) identification of the renewable energy programme as a priority scheme in the local economic development programme; b) provision of financial support from the state and attraction of participation by local investors; c) establishment of local teams of qualified technicians and provision of training for them through national and international cooperation; d) supporting of research, development, demonstration, transfer, and application of new and renewable energy technologies; and e) creation of an environment conducive to foreign investment in the development of the energy sector within the HKH region.

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Chinese type solar cooker, Lhasa, Tibet

Building retrofitted with sun space, Lhasa, Tibet

Solar water heaters on the roof top of an apartment building, Kunming, China

Solar exhibition, Kunming, China

Solar cooker and solar water heater fitted on the roof top of a toilet, China

Chapter 4

The Pattern of Energy Use in the HKH Region of India

by
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4.1 Introduction

4.1.1 General Situation

The Hindu Kush-Himalayan (HKH) region in India includes: (i) Jammu and Kashmir (J & K), Himachal Pradesh, Sikkim, Manipur, Meghalaya, Nagaland, Arunachal Pradesh, and the Mizoram States; (ii) Uttarakhand in Uttar Pradesh and the Darjeeling district of West Bengal; and (iii) Karbi Anglong, the northern Kachar Hills, Lakhimpur, Cachar, and Sonitpur (Darrang) districts of Assam. It has a population of more than 31 million (about 3% of the total population in India), of which 52 per cent are males. Nearly 82 per cent of the population live in rural areas. The total land area is 542.7 thousand sq. km., giving an average density of 57 people per km^2 compared to the Indian average of 257 people per km^2. Arunachal Pradesh is the most thinly populated area in the region with only 10 people per km^2. The average number of persons per household in the region is between five and six except in J & K where it is eight (CMIE 1987; India 1994).

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The main occupation is agriculture, mostly at a subsistence level. Fifty per cent of the people are labourers who work in the fields or in jungles (wood-cutters). The entire HKH region, particularly the whole of the northeast, is underdeveloped and poor in spite of having rich natural resources. Thus the rural population contributes significantly to the total energy needs of the region. Although the region is poor overall the per capita domestic product in all the states in the region compares well with the all-India average. The compound annual growth is quite good, particularly in the agricultural and manufacturing sectors (India 1994).

4.1.2 Climate and Natural Resources

Most parts of the Indian HKH, except Ladakh in J&K and Lahul Spiti in Himachal Pradesh are in the cold and cloudy region. Ladakh and Lahul Spiti are in the region of cold desert where forest cover is low. The rest of the region has a rich forest base, with an overall forest cover of 38 per cent. The forest cover in the western mountains (Himachal Pradesh, Uttarakhand, and Jammu and Kashmir) is lower (9-44%, with an average of about 27%), and in the eastern mountains (Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, the hills of Assam and West Bengal) higher (28-90%, with an average of about 55%) with the exception of West Bengal (7%) (FSI 1987; FSI 1989; TERI 1994; TERI 1996).

There are marked social, economic, and religious differences between the various HKH areas in India with distinct variations in such factors as literacy rate, occupation, poverty, and income. There are three distinct regions: the eastern mountain region (Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, the hills of Assam, and West Bengal); the central region (Himachal Pradesh and Uttarakhand); and the western mountain region (Jammu and Kashmir). The eastern and central regions are dominated by Hindus and Buddhists and the western region by Buddhists and Muslims. The literacy rate is lowest in J & K (22% compared to the national average of 52%), highest in Himachal Pradesh (64%, above the national average), and about the same in the eastern region and Uttarakhand (45%) (GOI 1996).

4.2 The Energy Resource Base

The main energy resources within the HKH region are hydropower, coal, oil, and fuelwood. The forest provides most of the energy used for household purposes, essentially cooking and space heating.

4.2.1 Traditional Energy Sources

The traditional energy sources in the HKH region are fuelwood, animal waste, and crop residues and, of course, animate power. The availability of these resources depends upon the land utilisation and cropping patterns. The total forest area and percentage of total land area covered by forest in the various HKH areas is shown in Table 4.1. There are good forest resources in most of the HKH states except Assam, J & K, Himachal Pradesh, and West Bengal. Data on crop production indicates that except in Assam and Himachal Pradesh, crop residues are not sufficient to meet the energy demands to any significant extent. However, a significant amount of animate energy is available in these regions. The estimated potential of animate energy (assuming 8 hours per day work for 360 days) is shown in Table 4.2.

Table 4.1: Total Forest Area (Recorded and Actual) as a Percentage of Total Land Area (1993 Assessment)

Description	Recorded forest area (sq.km)	Actual forest cover (sq.km)	land area (sq.km)	% forest area	% actual forest cover
Western Mountains	92,139	55,603	345,216	27%	16
Himachal Pradesh	37,591	12,502	55,673	68	22
Jammu and Kashmir	20,174	20,443	238,418	8	9
Uttarakhand	34,374	22,658	51,125	67	44
Eastern Mountains	120,017	151,881	219,748	55	69
Hills of West Bengal	1,011	697	9,376	11	7
Sikkim	2,650	3,119	7,026	38	44
Hills of Assam	9,314	7,433	26,701	35	28
Arunachal Pradesh	51,540	68,661	83,743	62	82
Manipur	15,154	17,621	22,327	68	79
Meghalaya	9,496	15,768	22,429	42	70
Mizoram	15,935	18,697	21,081	76	89
Tripura	6,292	5,538	10,486	60	53
Total Mountains	212,156	207,484	564,964	38	37
All India	770,078	640,107	3,29,3273	23	19

Source: TERI 1994; TERI 1996; CME 1996

4.2.2 Sun and Wind Energy Potential

Although the number of sunshine hours in the HKH region is less than the all India average of more than 2,500 per year, it is still large enough for effective utilization of solar energy. The annual mean of sunshine hours varies from 1,800 to 2,400. The number of sunshine hours per month, and the estimated amount of total solar radiation per month are shown in Table 4.3. The values shown are those measured in different parts of the region. There are no detailed measurements available for solar radiation over the entire HKH region of India, but the estimates are probably accurate to within 15 per cent.

Table 4.2: Animate Energy Potential in the HKH Region of India (in '000 GJ/annum)

HKH region	Animate Energy Available
Himachal Pradesh	24,000
Jammu and Kashmir	18,100
Arunachal Pradesh	1,700
Manipur	8,400
Meghalaya	4,000
Mizoram	55
Nagaland	280
Sikkim	610
Tripura	5,170

Sources: TERI 1994; TERI 1996

Note: 1 animal power taken to be 9.6 MJ

There are no figures available for other areas of the HKH Region of India.

Table 4.3: Average Number of Sunshine Hours and Total Solar Radiation Each Month in the HKH Region

Month	No. of sunshine hours	Monthly solar radiation (kWh/m^2)
January	200 to 220	63 to 120
February	180 to 220	80 to 140
March	220 to 260	110 to 145
April	200 to 240	110 to 150
May	160 to 300	160 to 220
June	120 to 200	120 to 200
July	120 to 180	130 to 170
August	140 to 240	140 to 180
September	160 to 220	116 to 160
October	180 to 260	120 to 130
November	200 to 260	120 to 130
December	200 to 220	80 to 120

Source: Bansal and Minke 1995

There are no wind monitoring stations in any of the HKH states. Some estimates show an annual mean wind speed of five kmph, which is too low for any wind energy system. There may be locations where wind speeds are much higher, but there are no measured data available to date.

4.2.3 Hydropower Potential

Hydropower is the most attractive source of renewable energy because of flexibility of utilisation, ready availability, and pollution free operation. The total hydropower potential in India is estimated to be 84,000MW (TERI 1996) of which more than 75 per cent is in the HKH region (Table 4.4). The actual power generating capacity in the region is comparatively very low, however. The rates of village electrification and number of households having electricity are shown in Tables 4.5 and 4.6. Although the total coverage of rural electrification looks good, in practice only houses in the more accessible and less remote villages have been connected to the electricity grid. The supply is usually of poor quality with high voltage fluctuations and long hours (and days) of no supply. The actual proportion of households with electricity is only about 30 per cent (Gupta 1997). One of the main reasons is that the majority of the people who in theory could benefit cannot afford the costs involved. An important issue in the rural electrification programme is that so far rural electrification has only meant extension of the conventional grid. There has been no provision for decentralised power generation and distribution. Because of this, remote and inaccessible villages in several parts of the country, where grid extension is neither logistically nor economically viable, have not been able to benefit from rural electrification (Dutta 1997). Many of these villages lie in the HKH region.

The estimated (potential) power that could be obtained from small, mini-, and micro-hydel stations in the region in India is 5,000MW mainly in Arunachal Pradesh, Himachal Pradesh, and Uttarakhand (CMIE 1995). Table 4.7 shows the number 'and capacity of installed mini- and micro-hydel stations (up to 3MW), of hydel

Table 4.4: Hydropower Potential (MW) and Plant Installed (more than 3MW Capacity) in the HKH Region

HKH Region	Hydropower Potential (MW)	Per cent in all India (%)	Installed capacity (MW)	Per cent in all India
ArunachalPradesh	26,756	32	5	<1
Assam	351	<1		
HimachalPradesh	11,647	14	265	1
Jammu and Kashmir	7,487	9	176	<1
Manipur	1,176	1		
Meghalaya	1,070	1	185	<1
Mizoram	1,455	2		
Nagaland	1,040	1		
Tripura		16	<1	
Sikkim	1,283	2	21	<1
Uttarakhand	9,744	12	1478	7
HillsofWestBengal	1,786	2	65	<1
Total	**63,795**	**76**	**2,211**	**11**
All India	**84,044**	**100**	**20,829**	**100**

Sources: CMIE 1995; TERI 1996

Table 4.5: Rural Electrification in Different Areas within the HKH Region of India

Description	Total No. of Villages		Percentage of Villages Electrified	
	1986-87	1993-94	1986-87	1993-94
Jammu and Kashmir	6,477	6,477	91	95
Himachal Pradesh	16,916	16,807	67	84
Uttarakhand*	14,950	14,950	38	74
Arunachal Pradesh	3,257	3,649	30	40
Manipur	2,035	2,035	38	80
Meghalaya	4,902	5,492	29	43
Mizoram	721	689	30	64
Nagaland	1,112	1,225	81	na
Sikkim	405	414	63	100
Tripura	5,215	5,215	41	68
Total	55,990	56,953	51	74

Sources: TERI 1996; Mehta 1997
* The data for Uttarakhand are for 1980-81 and 1991/92.

Table 4.6: Households with Electricity (in per cent) in Selected Areas of the HKH Region

Description	Rural		Urban		Total	
	1981	1991	1981	1991	1981	1991
Arunachal Pradesh	11	33	64	81	15	41
Manipur	10	42	48	75	20	51
Meghalaya	7	16	60	83	17	29
Mizoram	4	35	50	85	16	59
Nagaland	20	47	58	76	26	53
Sikkim	13	57	72	92	23	61
Himachal Pradesh	51	86	89	96	55	87
Jammu and Kashmir	52	n.a.	92	n.a.	61	n.a.

Sources: TERI 1996; Dutta 1998

projects under construction, and of suitable sites already identified, in the HKH region of India. Besides this, traditional water mills are used extensively for agro-processing and cottage industrial applications, and it is estimated that there may be around 200,000 such sites in operation today.

4.2.4 Conventional Energy Sources

There are significant coal reserves in the eastern mountains of India, although these amount to less than one per cent of the total reserves available (Table 4.8). The oil and gas reserves available within the HKH region comprise 21 and 24 per cent, respectively, of the total reserves in India. The production rate of these resources indicates that the oil reserves identified so far will last for 31 years, natural gas for about 75/years, and coal for more than 200 years.

Table 4.7: Number and Capacity of Installed and under Construction Micro- and Mini-Hydel Projects (up to 3MW capacity) and of Suitable Potential Sites in the HKH Region

Description	Project Installed		Under Construction		Identified Sites	
	No.	Capacity (MW)	No.	Capacity (MW)	No.	Capacity (MW)
Arunachal Pradesh	29	19.15	12	21.60	201	149.37
Assam	2	2.20			16	11.23
Himachal Pradesh	14	9.47	4	11.00	138	200.00
Jammu and Kashmir	11	4.35	9	11.19	9	0.36
Manipur	6	4.10	4	3.50	12	5.70
Meghalaya	1	1.51	2	0.20	6	1.02
Mizoram	9	5.36	9	8.80	27	22.06
Nagaland	5	3.17	4	5.50	8	7.50
Sikkim	14	9.66	2	3.20	9	11.80
Uttarakhand	46	26.78	28	22.60	12	1.15
West Bengal	5	7.46	5	9.70	7	10.40
Total	**142**	**93.21**	**79**	**97.29**	**445**	**420.59**

Sources: CMIE 1995; TERI 1996; Dutta 1998

Table 4.8: Distribution of Coal and Crude Oil (in million tonnes), and Natural Gas (in billion cu.m.) Reserves in the HKH Region of India

Description	Proven Reserves				Annual Production Rate[1]		
	Coal	Lignite	Oil	Gas	Coal	Oil	Gas
Assam[2]	191	n.a.	n.a.	0	n.a.	5.043	0
Meghalaya	89	n.a.	0	0	n.a.	0	0
Nagaland	3	n.a.	0	0	n.a.	0	0
Arunachal Pradesh	31	n.a.	n.a.	0	n.a.	0.035	0
Jammu & Kashmir	n.a.	90	0	0	n.a.	0	0
Total	**315**	**90**	**155.5**	**156.1**	**1.2**	**5.078**	**2.1**
India	**68600**	**n.a.**	**727.0**	**643.0**	**253.8**	**32.0**	**19.4**

Sources: CMIE 1995; TERI 1996

[1]Production figures are for FY 1994/95. [2]Estimate based on state figures.
There are no proven significant reserves in any of the other areas in the region.

4.3 Energy Consumption Patterns

The energy use patterns in the eastern mountains, the western mountains, and the whole HKH region in India are shown in Tables 4.9 to 4.12

Nearly 80 per cent of the total energy in the eastern mountains, and over 70 per cent in the western mountains are estimated to be consumed by the household sector (Table 4.9). Ninety-five per cent of the energy used by households is from biomass in the form of firewood, dung, and crop residues. In the eastern mountains firewood is the main source of energy for cooking and space heating. The dependence on firewood is not surprising since the eastern mountains have the highest concentration of forests in the whole country. For example, there are seven ha of forest per capita in Arunachal Pradesh, which is thinly populated. Even so, as a result of the rapidly depleting forest cover, the rural poor in remote mountain

Table 4.9: Final Energy Consumption Pattern in the HKH Region of India, FY 1994/95

Locations/Sectors	Biomass		Commercial Fuels		Total Energy	
	'000 GJ	Per cent	'000 GJ	Per cent	'000 GJ	Per cent
Eastern Mountains						
Household	206,432	93	8,799	16	215,230	78
Comm./Inst.	4,306	2	20,391	37	24,697	9
Industrial	11,900	5	10,091	19	21,991	8
Agricultural	0	0	2,055	4	2,055	<1
Transport	0	0	12,950	24	12,950	5
Total	222,637	100	54,285	100	276,923	100
Western Mountains						
Household	208,537	90	20,128	25	228,665	73
Comm./Inst.[1]	6,615	3	14,133	18	20,748	7
Industrial	16,488	7	17,664	22	34,151	11
Agricultural	0	0	5,186	7	5,186	2
Transport	0	0	22,308	28	22,308	7
Total	231,640	100	79,419	100	311,059	100
Mountain Total						
Household	414,969	91	28,926	22	443,895	75
Comm./Inst.	10,921	2	34,524	26	45,445	8
Industrial	28,388	6	27,754	21	56,142	10
Agricultural	0	0	7,241	5	7,241	1
Transport	0	0	35,257	26	35,257	6
Total	454,278	100	133,704	100	587,981	100
Total Population (in thousands)					19,700	

Source: Study estimates
[1]Comm./Inst. = Commercial/Institutional

Note: The eastern mountains include Sikkim, Arunachal Pradesh, Manipur, Mizoram, Meghalaya, Tripura, Nagaland, the hills of West Bengal and Assam. The western mountains include Himachal Pradesh, J & K, and Uttarakhand.

Table 4.10: Biomass Energy Consumption Patterns in the HKH Region of India

Fuel type Sector	Fuelwood kg per capita	Agricultural Residues kg per capita	Animal Dung kg per capita
Eastern Mountains			
Household	694	135	73
Comm./Inst.	16	0	0
Industrial	49	0	0
Total	758	135	73
Western Mountains			
Household	577	65	88
Comm./Inst.	22	0	0
Industrial	37	17	0
Total	635	81	88
Mountain Total			
Household	629	96	82
Comm./Inst.	19	0	0
Industrial	42	9	0
Total	690	105	82

Source: Study estimates

areas are being forced to spend more time collecting fuel, or to use other forms of biomass energy such as crop residues and dung. A few micro-level studies have been conducted that highlight the predominance of biomass fuels, especially fuelwood, in the consumption pattern. These studies show that consumption patterns are affected by various factors such as sociocultural differences, family size, season, and resource availability.

Figures for the consumption of crude oil are only available for the whole of each of the states in the HKH region, not for the HKH areas alone. Apart from Assam, none of the areas in the HKH region is a major consumer of crude oil, even though about 15 per cent of the total Indian production comes from the eastern mountains. Consumption of coal is also marginal in the HKH region. The principal use of coal is in thermal power stations.

The following inferences can be drawn from these tables:.

(i) Seventy-seven per cent of the total energy consumed in the mountains comes from traditional fuels, 23 per cent from commercial fuels.
(ii) Sixty-five per cent of total energy consumption is in the form of fuelwood, 91 per cent of which is consumed by the household sector, six per cent by the industrial sector, and three per cent by the commercial/institutional sectors. The agricultural residues and animal dung used are consumed almost entirely by the household sector.

Table 4.11: Commercial Energy Consumption Patterns in the HKH Region of India

Locations/Sectors	Coal and Coke		Petroleum Fuels		Electricity		Total commercial	
	MJ/ Capita	Per cent	MJ/ Capita	Per cent	MJ/ Capita	Per cent	MJ/ Capita	Per cent
Eastern Mountains								
Household	8	32	539	17	54	11	600	16
Comm./Inst.	10	42	1,258	39	123	26	1,391	38
Industrial	6	26	431	14	251	52	688	18
Agricultural	0	0	86	3	54	11	140	4
Transport	0	0	883	27	0	0	883	24
Total	24	100	3,197	100	482	100	3,702	100
Western Mountains								
Household	7	9	761	23	333	36	1,101	25
Comm./Inst.	7	9	677	20	90	9	773	18
Industrial	63	82	483	14	421	45	967	22
Agricultural	0	0	188	6	96	10	284	7
Transport	0	0	1,221	37	0	0	1,221	28
Total	77	100	3,329	100	940	100	4,346	100
Mountain Total								
Household	7	14	662	20	209	28	878	22
Comm./Inst.	8	15	936	29	104	14	1,048	26
Industrial	38	71	460	14	345	47	843	21
Agricultural	0	0	142	4	77	11	220	5
Transport	0	0	1,070	33	0	0	1,070	26
Total	53	100	3,270	100	736	100	4,060	100

Source: Study estimates.

(iii) LPG represents a substantial proportion of the total petroleum fuels consumed. Twenty-nine per cent of the total energy from commercial fuels is consumed by the commercial and institutional sectors, 33 per cent by the transport sector, 14 per cent by the industrial sector, 20 per cent by the household sector, and only four per cent by the agricultural sector.

(iv) In the eastern mountains, 80 per cent of total energy is supplied by traditional fuels, in the western mountains 74 per cent. Fuelwood contributes 67 per cent of total final energy in the eastern mountains, and 62 per cent in the western mountains. The per capita consumption of fuelwood is higher in the eastern mountains than in the western mountains (758kg versus 635kg).

(v) Commercial fuels provide 20 per cent of total final energy in the eastern mountains (3,702 MJ per capita) and 26 per cent in the western mountains (4,346 MJ per capita). Petroleum fuels contribute 86 per cent of total energy from commercial fuels in the eastern mountains, and 77 per cent in the western mountains.

Table 4.12: Percentage of Households Using Different Types of Fuel for Cooking (1991 Census)

Locations	Cow Dung	Electricity	Coal/ Coke	Charcoal	LPG	Wood	Biogas	Kerosene
Arunachal Pradesh	<1	<1	<1	<1	4	88	<1	6
-Rural	<1	<1	<1	<1	2	94	<1	3
-Urban	<1	<1	<1	<1	20	52	<1	<1
Himachal Pradesh	<1	<1	<1	<1	6	82	<1	9
-Rural	<1	<1	<1	<1	2	91	<1	5
-Urban	<1	1	<1	<1	40	15	<1	41
Manipur	<1	<1	<1	<1	6	86	<1	3
-Rural	<1	<1	<1	<1	2	92	<1	1
-Urban	<1	<1	<1	<1	19	68	<1	9
Meghalaya	<1	<1	<1	2	3	85	<1	7
-Rural	<1	<1	<1	<1	<1	97	<1	<1
-Urban	<1	2	1	10	18	35	<1	32
Mizoram	<1	<1	<1	<1	8	75	<1	14
-Rural	<1	<1	<1	<1	<1	97	<1	<1
-Urban	<1	<1	<1	<1	18	51	<1	30
Nagaland	<1	<1	<1	<1	3	93	<1	3
-Rural	<1	<1	<1	<1	<1	98	<1	<1
-Urban	<1	<1	<1	<1	10	75	<1	13
Sikkim	<1	<1	<1	<1	2	74	<1	21
-Rural	<1	<1	<1	<1	1	82	<1	16
-Urban	<1	<1	1	<1	16	9	<1	70
Tripura	<1	<1	<1	1	3	91	<1	2
-Rural	<1	<1	<1	1	<1	96	<1	<1
-Urban	<1	<1	<1	3	17	68	<1	10

Source: GOI 1992

LPG = liquified petroleum gas

(vi) The per capita electricity consumption is three times higher in the western mountains than in the eastern mountains (261kWh versus 134kWh).

(vii) The share of commercial fuels increases with the rate of urbanisation as well as with the development of physical infrastructure, as seen, for example, in the case of Himachal Pradesh and Sikkim.

The total energy consumption in the HKH region is 588 million GJ, 17,852 MJ per capita for a population of 31 million. The corresponding GNP (gross national product) is about US$ 350. This compares very well with the national average, which at present shows a 3.2 per cent growth rate corresponding to a per capita energy consumption growth rate of 6.2 per cent (GOI 1996). As commercial fuels become more readily available, both the total and the per capita consumption of commercial energy are likely to increase.

Electricity is the most desired form of commercial energy, and there is a rapid growth in electricity consumption per capita. Even so, the supply is still 15 to 25 per cent lower than needed to meet the present demand (CMIE 1995). It is very unlikely that this deficit can be met by conventional energy because of the resource constraints.

4.4 Energy Use Variability

Energy use in the HKH region is firmly correlated with the natural resource base and varies from area to area depending upon the pressure from various components of the system such as grazing and agriculture.

The following discussion on differences in energy use in the various areas within the Indian HKH is based on available information.

4.4.1 The Eastern Mountains

Nearly 70 per cent of the energy consumed in the eastern mountains is used for household purposes, and more than 80 per cent of households use firewood as their only source of energy for cooking and space heating.

Meghalaya

There are some survey reports (see Table 4.13) on Meghalaya that contain information on variations in energy use. The per capita annual consumption of firewood (1993 survey) varies with farm size (Table 4.13). There are seasonal variations in fuelwood consumption, consumption in winter is 12 per cent more than in summer. The consumption of branches and twigs was found to be 210kg using a yesterday-recall-method, and 194kg using a seasonal-recall-method, which is substantial in terms of total fuelwood consumption. The values for total average per capita fuelwood consumption also varied depending on the survey method employed, 858kg by the seasonal-recall-method and 831kg by the yesterday-recall-method. Actual measurements showed a fuelwood consumption of 861kg.

Kerosene is used in about 20 per cent of households for cooking. The per capita annual consumption was 51 litres with some seasonal variation.

All rural and urban households were found to use a simple construction of stone and mud, a traditional *chulha* (stove), for cooking. No improved stoves were found to be in use.

Water heating, space heating, and preparation of cattle feed are the other important household activities requiring energy. Water is heated for bathing, washing, and even drinking purposes. The general practice is to keep a vessel containing

Table 4.13: Per Capita Consumption of Fuelwood (Wood only) and Kerosene by Farm Size in Dalu Block, Meghalaya

Description	Wood (kg)	Kerosene (Lit)
Large farmers	646	45
Small farmers	572	38
Marginal farmers	649	28
Agricultural labour	648	17
Non-agricultural labour	651	14
Artisans	718	73
Others	650	25
Mean	648	51

Source: IREP 1993

water over the stove after cooking is complete. Space heating is necessary in winter, but is mostly only done together with cooking. Use of kerosene and charcoal for heating water or space heating was negligible.

There is a wide variation in the numbers of households with electricity, from five to 45 per cent in different blocks of a district. Electricity is used mainly for lighting. Usually, there are only about two points in a household. Large and marginal farmers had more than two points. Usually not all rooms are provided with a connection. People mainly use electricity for lighting only. Per capita electricity consumption varies from 0.3 to three kWh per month. The consumption of electricity is really very low, because even in villages with electricity the number of households connected to the supply is small. Households without electricity use kerosene for lighting. Kerosene consumption is reported to be 1.1 to 1.4 litres per capita per month. There is a variation according to household size.

Sikkim

Eighty-seven per cent of the total energy consumed in Sikkim comes from wood. Most of this is used in the household sector. As a result of the increasing time needed for fuelwood collection, per capita energy consumption is falling in this region. Recently people have started to buy wood. Agricultural residues and kerosene supply eight per cent and five per cent of total energy requirements and electricity a mere 0.3 per cent (DA 1988).

Energy consumption is fairly uniform across the region, but the actual energy consumption in a household depends on factors such as family size. Per capita energy consumption in Sikkim decreases with family size, in contrast to Uttarakhand where it increases with family size. Variations in fuel consumption have also been noted between different communities as a result of the variation in cooking and eating habits.

Some general trends are seen. LPG is being used increasingly for cooking in the household sector. Electricity and petroleum consumption are also on the increase. It is expected that energy consumption will grow further, and the supply-demand gap may increase unless alternatives with lower investment costs are found.

4.4.2 The Western Mountains

Jammu and Kashmir

The per capita rural household energy consumption in J & K is reported to be 8,119.6 MJ, which is much higher than the north Indian average of 6,091.39 MJ. The fuel mix, however, is not as strongly dominated by firewood as in other hill regions. Fuelwood accounts for 59 per cent of total energy consumed, cowdung 24 per cent, kerosene nine per cent, electricity four per cent, and agricultural residues 3.5 per cent. Some micro-level studies, however, show a different consumption pattern. For example, one study found that, despite low forest cover, nearly 80 per cent of energy came from firewood and its by-products (Alam and Hussain 1987). Much larger quantities of fuel are consumed in the winter than in the summer. The per capita consumption per household per month rises from 160 to 280kg for firewood, from 160 to 240 litres for kerosene, and from 40 to 90kg for cowdung. Kerosene is not available at very high altitudes, and there the main energy sources are wood and dung.

Himachal Pradesh

The per capita energy consumption in Himachal Pradesh is high, 10,812 MJ or nearly double that of the north Indian rural average. Most energy comes from firewood. The per capita consumption of fuelwood varies between districts, from 1,091kg in Mani district to 980kg in Shimla and only 480kg in Solan. This variability obviously results from both the availability of wood and the prevailing climatic conditions.

Uttarakhand

The eight hill districts of Almora, Nainital, and Pithoragarh in the Kumaon Hills and Chamoli, Pauri, Dehradun, Tehri, and Uttarkashi in the Garhwal Hills are collectively known as Uttarakhand. These districts are located in the northwestern part of Uttar Pradesh. Most energy is consumed in the form of the firewood used for cooking and space heating in the household sector (GIDS n.d.).

The annual per capita consumption of firewood varies from village cluster to cluster, but lies in the range of 16,120 – 18,126 MJ. Villages situated at high altitudes (5,000 to 7,000masl) consume more firewood than villages situated at lower altitudes (300masl), as they need it for space heating. Economic status of the family and availability are the two main factors that influence kerosene consumption, the other important fuel and which is used mostly for lighting. Kerosene consumption also varies from village cluster to cluster from 242 MJ to 1,422 MJ. One very distinct feature of the energy mix in this region is the near total absence of dung as fuel, because dung is used here as manure (Swaminathan 1982; Jackson 1982; Moench 1985; Todaria 1990).

4.5 Renewable Energy Technologies

Renewable energy Technologies (RETs) were initially installed in the HKH region for demonstration purposes and were later disseminated actively when the tremendous potential of these technologies to negate impending environmental degradation was realised. The main technologies that have been demonstrated and disseminated are improved cooking stoves, biogas plants, solar photovoltaic equipment, and mini- and micro-hydropower plants. The number of units or capacity of such technologies installed in different parts of the Indian HKH region are shown in Table 4.14.

Improved cooking stoves and family-sized biogas plants are the most disseminated technologies within the HKH region of India. The Indian mountains should be a good area for the installation of mini- and micro-hydropower plants, with almost 2,000MW of potential in the region, but at present only about 52MW are exploited. The western mountains show significant use of solar energy technologies (Dutta 1998).

Manufacturing of various renewable energy systems has matured in India as a result of the promotional efforts of the government. There are 74 manufacturers of solar photovoltaic and wind power systems, and although these are all located outside the HKH region, they are capable of providing services within the region as well. Household-type biogas systems have been installed all over India, primarily by the Khadi and Village Industries' Commission (KVIC). Local craftsmen produce improved cooking stoves. There are a number of biomass gasifier designs available, and several mechanical factories located in different parts of India are capable of producing these units. Almost all mechanical factories are able to construct mini- and micro-hydropower plants if appropriate designs are provided.

4.5.1 Improved Cooking Stoves

Improved cooking stoves, which have a minimum thermal efficiency of 20-25 per cent compared with 5-10 per cent for traditional cooking stoves, have a number of benefits in addition to fuel saving such as reduction in health hazards as a result of the elimination of smoke, reduction in air pollution, and cleaner homes. By April

Table 4.14: Renewable Energy Technologies in the HKH Region of India

Descriptions	Unit	All India	North East	HP	J&K	Sikkim	Total
Family-size Biogas Plants	No.	2,367,798	204,293	37,871	1,297	1,606	245,067
Improved Cookstoves	No.	19,611,272	118,556	528,527	256,796	35,965	939,844
Solar Thermal Systems							
-Domestic type	No.	12,517	18	819	33	21	891
-Industrial type	No.	6,142	151	143	72	26	392
Solar Cookers	No.	288,028	1,002	13,349		20	15,373
PV Water Pumps	No.	463			4		4
PV Plants	kWp	N.A.	39		39		
PV Systems	kWp	3,605	273	39	48	12	372
Wind power	kW	732,600				0	
Small & Micro-	No.	161	50	13	6	6	75
Hydropower	MW	120	33	9	3	7	52
Biomass gasifiers/ Stirling Engines	No.	1,604	10	2	4		16

Sources: TERI 1996; Dutta 1997; Dutta 1998

Note: The northeast region includes Manipur, Meghalaya, Mizoram, Nagaland, Arunachal Pradesh, and Assam and corresponds to the eastern mountains but without Sikkim, Tripura, and the hills of Assam and West Bengal. Information on Uttarakhand, and the hill districts of West Bengal and Assam is not included as information is only available at the state-level and these areas represent only a small proportion of the states of which they are a part. Values for biogas and wind power are up to March 1996; for improved cookstoves, PV water pumps, mini- & micro-hydropower and biomass gasifiers up to April 1995; for solar thermal systems, solar cookers, and PV systems up to March 1993.

1995, about 20 million improved cooking stoves had been installed in India with an average fuel saving per stove of more than 700kg of wood per annum (the estimated total saving if all stoves are used fully to replace traditional models is equivalent to IRs 5,000 million or 500 crores).

So far, nearly one million improved cooking stoves have been installed in the HKH region of the country. Several studies have been conducted to assess the acceptability of these stoves in hilly regions. A study conducted in the Garhwal hills of Uttar Pradesh (Dutta 1977) revealed that 54 per cent of the beneficiaries were using the improved cooking stoves to cook all their meals, while another 17 per cent used them only during the winter and 17 per cent did not use them at all. A more recent study conducted in the northeast by TERI showed that overall acceptance of the fixed mud-type improved stove was low (Dutta 1997). The primary reason was the incompatibility of traditional cooking practices and the features of the model introduced. In most hilly areas, the traditional cooking stove performs the multiple functions of cooking, space heating, smoking and drying of agricultural products, and, at times, lighting. The commonly promoted fixed, smokeless models have not been able to address these requirements and hence have had a limited acceptability. The metal portable stoves have found better acceptance in mountain communities than the fixed stoves, although people have used them primarily for space heating.

4.5.2 Mini- and Micro-hydropower

The Indian Himalayas possess a vast hydropower potential which needs to be exploited. However, given the operational and capital constraints, large hydel projects are not an easy option. Mini- and micro-hydel schemes (up to 1MW) can provide a viable alternative for meeting location specific end-uses such as agro-processing, irrigation, and lighting.

The history of mini- and micro-hydropower (MMHP) in India dates back to 1897 when a 30kW plant was installed in Darjeeling in West Bengal. The success of this project led to the installation of several other plants during that period, many of which are still working at full capacity. Power generated from these projects was used mainly for lighting of nearby small towns. While hill streams in the Indian Himalayas were first harnessed for generating electricity in the late nineteenth century, they had been used to provide mechanical power for such applications as grinding grain for hundreds of years. Although the exact number of such watermills is not known, it is estimated that there may be around 200,000 sites in operation today (Kumar 1997). Government emphasis on mini- and micro-hydropower began in earnest in the 1980s. By March 1996,a total capacity of 52MW had been installed in different hill states.

A number of evaluations has been carried out by different agencies to assess the performance of existing MMHP plants (Dutta 1997). An evaluation study carried out in the northeast showed that several systems that were sanctioned in 1989-90 have still not been completed. The time and cost overruns have mainly resulted from financial constraints and inadequate management. Of the four MMHP commissioned recently, only one was found functional. The primary reason for plants not being operational is damage caused by floods during the monsoon which has never been repaired or failure of components. Another study conducted by TERI, which reviewed and documented the status of MMHP in India, showed that most of the functional plants are operating at sub-optimal capacity, the primary reasons being low load factor, lack of people's involvement, and technical and operational problems such as siltation, damage to civil works caused by floods, and absence of workshop facilities in remote mountain locations (Dutta 1998).

4.5.3 Biogas Plants

Biogas generated from cattle and/or human waste and other biomass is a cheap and convenient fuel which has the added advantage of increasing soil fertility. Biogas is largely used for cooking, but can also be used for a variety of end uses such as lighting and power generation. The main requirement for setting up a biogas plant is the availability of biomass and water.

Nearly 2.4 million family-sized biogas plants have been installed in the country so far under the National Project on Biogas Development (NPDB). These plants are thought to save the equivalent of IRs 10,000 million (1,000 crores) annually in fuelwood and fertilizer. More than 245,000 plants have already been installed in the HKH region of India (Table 4.14). Various evaluation reports on biogas plants indicate that the percentage of functional biogas plants varies from 65 to 90 per cent in different states (the range in the northeast is 67-90 per cent with Assam the best at 90%) (Dutta 1977). The study conducted by TERI in the northeast, however, showed that only 24 per cent of the plants surveyed were actually in operation (Dutta 1997). The performance of biogas plants in Himachal Pradesh has been significantly better than in other hilly regions. It seems that biogas plants have not performed satisfactorily in the hills only if you take the TERI study to be right and the one before to be less reliable in spite of the higher level of subsidies offered than in the plains. The main reasons for non-functionality were shortage of dung, installation of over-sized plants, poor siting of plants, inadequately trained field staff, and lack of maintenance for the plants installed. The problem of maintenance is common throughout the country, but it has more severe implications in the hill and remote areas where it is difficult for the plant owner to inform the implementing agency because of the remoteness. The high livestock population in the eastern mountains, including a significant pig population, suggests that there is a higher potential for biogas development there than in the western mountains.

4.5.4 Solar Photovoltaic Technology

Solar photovoltaic (SPV) systems, which allow power to be stored and then used as required, are ideal systems for small-scale end-uses such as lighting, pumping water, and low temperature storage of medicine. In remote mountainous locations, where the normal grid is difficult to reach, this can be a very viable alternative. Several systems, used primarily for household lighting and operation of TV sets, function in remote locations in the northeast and Ladakh. A recent study conducted by TERI, however, revealed that nearly 50 per cent of the village-based systems in the northeast are currently non-functional (Table 4.15). The only devices still functioning at a high level were solar lanterns.

Table 4.15: Status of Solar PV Devices in some Northeast States

States	Street Lights	Domestic Lights	Power Packs	Lanterns	Irrigation Pumps
Arunachal	269(187)	5(3)	4(3)	7(7)	
Assam	18(18)	300(200)			3(2)
Manipur	5(1)				2(0)
Meghalaya	13(6)			3(3)	
Mizoram	7(7)				2(0)
Nagaland		30(1)			
Total	312(219)	335(204)	4(3)	10(10)	7(2)

Source: Dutta 1997

Note: Numbers in parentheses indicate the number of functional devices.

The main problem with SPV systems is that the users are not responsible for maintenance as the systems are heavily subsidised. Especially in the case of devices installed for community use, such as street lighting systems, the users have an indifferent attitude and problems such as vandalism and theft are common. The difficult terrain and poor infrastructure also result in problems such as lack of availability of spare components, component failures, and lack of trained technicians. Notwithstanding the importance of these problems, the biggest gap in programme dissemination is the lack of training of users in system maintenance, and lack of programmes to build local level capacity in maintenance.

4.5.5 Solar Thermal Systems

Technologies for solar water heating systems and solar cookers have been developed and are being distributed commercially throughout the country. Solar thermal systems for various other applications such as solar air heating, crop drying, timber seasoning, and water desalination have also been developed and action plans are being prepared for their commercialisation. Solar water heating systems have a vast potential for saving the electricity used in the household and commercial sectors and the furnace oil used in the industrial sector for heating water.

A number of solar thermal devices has been installed in the HKH region of India (Table 4.14), but their overall performance has been mixed. A study conducted by TERI revealed that apart from in Arunachal Pradesh, the proportion of systems installed under the North East Council (NEC) schemes that were still functioning was less than 50 per cent. The main operational problems faced in the operation of solar water heating systems in the hilly regions were damage caused by rain and hailstorms, breakage of glass panels, rust formation, insulation material getting damaged over time, and pipeline leakages.

4.5.6 Biomass Gasifiers

Given the abundant availability of biomass resources, especially wood, biomass gasification appears a promising alternative for power generation and other uses in hilly regions in India. In the northeast, wood-based gasifiers have been promoted as demonstration units, mainly in wood-based industries such as saw mills and a few silk reeling units (Dutta 1997). These systems have performed poorly. There are two main reasons. First, wood has to be chopped into small pieces for the gasifiers, and this operation requires extra manpower thus increasing the overall cost. Second, as electricity is highly subsidised (the tariff for industry is between IRs 2.5-3 per unit), generating electricity using a gasifier works out to be more expensive than purchasing electricity from the State Electricity Board (SEB). There have been some efforts to use different types of weed available in the hills, which otherwise would have to be disposed of – mainly thermally. Some preliminary work in this direction is being carried out by an NGO, the Himalayan Environment and Science Conservation Organization (HESCO), in Uttarakhand. HESCO has used a locally growing weed, lanatana (*Lanatana camara*), for gasification. So far no detailed scientific studies have been conducted on its performance, however.

4.5.7 Learning from the Experience of RETs in the Indian Himalayas

The experience of RETs (renewable energy technologies) in the Indian Himalayas shows that there are several gaps in the existing set-up that hinder their performance. There are technology specific barriers, as well as barriers common to all programmes and technologies. The main barriers to large-scale dissemination of different technologies are summarised in Box 4.1. The basic constraints to the diffusion of technologies in the hill regions are related to the geographical and physical infrastructure.

The low levels of income and awareness of the population hinder the process of adoption of technologies and necessitate subsidising the cost of these, at least for

Box 4.1: Barriers to Dissemination of RETs in the Indian Himalayas

Technology	Barrier to large-scale dissemination in present form
Micro- and Mini-Hydropower	Inadequate work on load-developing strategy Basic field data not available-Technical and operational problems not yet solved
Improved Cooking stoves	Existing models incompatible with region-specific traditional lifestyle-Inadequate attention to R & D
Biogas Plants	Issues of low ambient temperature and low dung availability not resolved
Solar Photovoltaic Systems	High initial investment requirement
Solar Thermal Systems	Technology not yet mature for the mountains
Biomass Gasifiers	Uneconomical, because of subsidised electricity and diesel fuel
Wind Energy	Wind monitoring and mapping data not available for many places

Source: Dutta 1997.

the majority of the target group. Furthermore, the difficult terrain, working conditions, and poor physical infrastructure make it extremely difficult to set in place repair and maintenance networks, and this adversely affects the reliability and performance of the installed devices.

Not enough effort has been made to develop local manufacturing facilities for RETs in the Indian Himalayas. As a result, all the equipment has to be imported from the plains, leading to an increase in costs.

The product development for many of the technologies, such as biomass gasifiers, improved cooking stoves, solar thermal systems, and biogas plants, has not reached a stage at which they can be taken up for large-scale dissemination. Research and development are still needed to integrate the specific needs resulting from climatic and weather constraints and sociocultural conditions.

Although RETs have not been entirely successful in terms of ensuring satisfactory performance of the installed devices, renewable energy policies have at least contributed to the deployment of a large number of devices in the Indian Himalayas. Several policies, such as the incentive packages for private sector participation in the MMHP sector, have been announced only recently and their impact has yet to be seen.

4.6 Energy Prices and Price Setting Mechanisms

Energy prices are administered in India, and do not reflect the actual cost to the nation. In fact, some energy products have been subsidised to such an extent that the supply industry has not been able to generate adequate resources internally to expand rapidly enough to keep pace with rising demand. Shortages of coal and power over the past decade or so are largely a consequence of such a pricing regime.

4.6.1 Pricing of Fuelwood and Charcoal

The information available indicates that fuelwood prices in urban areas and market towns rose substantially during the 1980s, perhaps reflecting the need to transport it over increasing distances in lorries using diesel to run. In contrast, there is no cost attached to fuelwood in rural areas, apart from that for collection and transportation. A certain proportion of the fuelwood brought to the cities is not sold directly to consumers but converted to charcoal in rather inefficient kilns. The price of charcoal has also increased significantly.

4.6.2 Pricing of Coal

Coal prices are set below production costs, although the difference between the average cost of production and the sale price of coal at the pit-head is narrowing. In fact, there seem to be certain basic flows inherent in the method adopted for fixing coal prices. The coal production costs of all mines are averaged, which allows uneconomic mines to co-exist with more efficient ones. As costs are averaged, losses in individual mines are ignored, and proper identification of mines for priority investment is not possible.

Coal comes in many different grades; and even within each grade there are wide differences in the useful heating value (UHV). However, the price for each grade does not reflect such differences - it is based on the lowest UHV in a specified range of each grade. As a result, coal producers have no incentive to supply coal of a higher heat value. Moreover, the entire pricing procedure focusses only on pit-head costs; it ignores the costs incurred in delivering the coal to the consumer. Differences in the prices of coal of different grades at the pit-head are lost entirely by the time the coal reaches the consumer as a result of the high cost of transport. Consumers, therefore, continue to use high grades of coal (which are scarce) because they see no economic benefit in switching to lower grades.

4.6.3 Pricing of Petroleum Products

The prices of petroleum products are fixed by the government from time to time for various stages of the supply industry. Pricing is a complex issue because India imports crude oil as well as producing indigenous crude oil from onshore and off-shore fields. The crude oil prices paid to the petroleum exploration and development organizations are decided not only on the basis of costs incurred in the exploration but also on the basis of international crude oil market conditions and the financial requirements for expanding exploration and production activities. The imported crude oil, on the other hand, is priced on the basis of its landed cost plus handling charges, customs duty, and other costs. The prices of both domestic and imported crude oil are pooled in the Crude Oil Price Equalisation Account, so that all refineries are supplied crude oil at a uniform price. Fixing retention prices for refineries is aimed not only at providing an incentive for efficient refining operations but also at rationalising the refinery output-mix in line with the demand-mix while ensuring the financial viability of refining companies. This translates into each refinery fixing its own retention price for each product. Relative prices are indexed with reference to kerosene based on its cost of production by that refinery. This cost relates to the efficiency of operations, and includes the use of common pipeline facilities. Finally, consumer prices are fixed on the basis of certain social considerations. These prices are administered through a series of pool accounts. The weighted average of distribution costs for each product is incorporated in the price build-up, so that the price of a particular product is uniform all over the country. Any difference in consumer prices from one state to another is due largely to differences in the tax rates levied by the respective state governments.

The weighted average of consumer prices has been maintained at parity, or higher than across the border prices. Cross-subsidising of products has posed certain problems. The selling price of kerosene has been consistently maintained much below the cost of supplying it, to make it affordable to large sections of the population. Moreover, over the past two decades, the increase in the price of kerosene has been much lower than that of other petroleum products. Because kerosene is far cheaper than diesel, it is used to adulterate diesel in the transport sector. At the same time, the scarcity caused by this diversion to other end uses has forced consumers to buy kerosene on the black market at a much higher price. Similarly diesel is much cheaper than petrol, and this has prompted owners to retrofit their vehicles with inefficient diesel engines. These pricing policies have therefore resulted in further increasing demand for kerosene and diesel, both of which are middle distillates and are being imported.

4.6.4 Pricing of Natural gas

Until 1987, the gas producing companies (Oil and Natural gas Corporation [ONGC]) and Oil India Ltd) priced natural gas in an ad hoc manner. The government fixed the price of natural gas in 1988, but these prices neither reflected the imported gas price nor the opportunity cost of natural gas to the consumer. Instead, they were based on the cost of gas production from the South Bassein field, allowing an assured return to the producer. The price of gas for the northeastern region was set somewhat arbitrarily, since the gas, if it hadn't been sold, would have been flared. In 1989, these prices were revised. An attempt was made to link the price of gas to the economic value of imported fuel oil, though the linkage is neither complete nor based on a formula that permits an automatic change in the natural gas price corresponding to any change in the economic value of imported fuel oil. This price applies to a calorific value of 9,000-9,500 kcal per m^3, with a proportionate rebate or premium if the actual calorific value turns out to be less than 9,000 or exceeds 9,500 kcal per m^3.

These prices are also subject to sales' taxes and royalties. The state governments are paid a royalty of 10 per cent on the sale price of natural gas produced within the state. No royalty is paid for gas produced offshore. In addition, a sales' tax is payable to the state governments on the gas sold within a state. The rates of sales' tax vary from state to state, ranging from no tax to a tax of 19 per cent.

4.6.5 Pricing of Electricity

The average electricity tariffs are usually below the costs of power generation and supply. As a result, the electricity utilities have generally found it difficult to expand their generating capacity to keep pace with rising demand, or to modernise their facilities. The problem is compounded further when, as a result of lack of adequate financial resources, project implementation is slow, leading to substantial cost overruns and a further rise in supply costs. At the same time, strengthening and expanding the transmission grid has not been given adequate consideration as the investment allocated for transmission projects is reallocated for generation schemes. Moreover, as the rural electrification programme has continued to expand, an increasing share of electricity is consumed in the agricultural sector - which has the lowest tariff, although the costs of supplying power to this sector are probably the highest. Apart from the overall tariff being much below the average costs, it is in the form of a 'flat rate' tariff. Consumers are charged a flat rate based on their connected load (per HP of pump set) irrespective of the hours of use. The flat rate tariffs encourage misuse and wastage of electricity.

The basis for setting electricity prices should be very different from those for coal or petroleum products because electric power cannot usually be stored - which means that the cost of meeting power requirements varies with the time of day. The tariff during peak hours of demand should be higher than that during off-peak hours, at least for major electricity consumers. Also, the electricity tariff should be based on the long-run marginal cost of production, transmission, and distribution. This practice, however, has not been generally adopted in India so far. An appropriate tariff structure could play a significant role in demand management and promoting the rational use of electricity.

4.7 Review of Energy Planning Approaches and Institutional Arrangements

During the Sixth (1980-85) and Seventh Plans (1985-90) emphasis was placed on evolving a rational pricing policy to reflect the true resource costs of energy production and supply to the economy. However, the regime of administered prices with implicit subsidies continues to exist, despite the recent price adjustments implemented in the case of some oil products. A tariff structure that does not fully reflect the cost of production and supply of domestic or imported energy resources is not conducive to promoting the efficient use of energy and optimum inter-fuel substitutions. Moreover, such a tariff structure does not provide sufficient returns to the producing agencies to enable them to expand or modernise their operations in tune with the growing demand for energy. It is, therefore, imperative that a rationalised tariff structure be adopted with respect to the different forms of energy. If subsidies are inescapable from the point of view of socioeconomic imperatives, the target groups concerned need to be identified and subsidies restricted strictly to the target groups only. Indeed, alternative means of delivering the intended benefits to those target groups need to be carefully examined. This is particularly relevant in respect of electricity and certain petroleum products such as LPG and kerosene. The tariff structure should be such that it optimises the use of energy for alternative productive purposes.

4.7.1 Long-term Energy Planning

Several expert bodies in the past, such as the Energy Survey of India Committee (1965), the Fuel Policy Committee (1974), the Working Group on Energy Policy (1979) and the Advisory Board on Energy (1983-88), have emphasised the need for integrated long-term energy planning (WGEP 1979). The Planning Commission has, therefore, carried out studies on the long-term energy supply and optimisation of the demand system. However, the earlier Five Year Plans have tended to reflect short-term and medium-term concerns more than the long-term policy imperatives in energy planning. The emphasis of the earlier Plans was on supply problems in the sector rather than on economy in the end-use of energy through conservation (Sengupta 1993). In the Eighth Plan (1990-95) importance has been given to long-term integrated planning with emphasis on energy end use as well as on an efficient strategy for the long-term energy supply. The studies of the Planning Commission need to be updated from time to time, depending on the changes taking place in the internal and external environment, and to be used as a basis for integrated energy planning.

4.7.2 An Energy Strategy for the Future

It is desirable to adopt a long-term energy strategy that is consistent with sustainable development. Such a strategy should ensure that the highest priority is accorded to meeting fully the basic energy needs of the rural and the urban poor in the immediate future. It should also ensure a gradual shift from non-renewable resources to renewable ones with increasing emphasis on demand management, conservation, and efficiency. The short-term, medium-term, and long-term priorities should be as follows (GOI 1991; GOI 1992).

Short-Term

a. Maximise returns from the assets already created in the energy sector
b. Initiate measures for reducing technical losses in production, transportation, and end use of all forms of energy
c. Initiate action to reduce the energy intensity of the different energy consuming sectors of the economy and to promote conservation and demand management through appropriate organizational and fiscal policies
d. Initiate steps for meeting fully the basic energy needs of both rural and urban households, so as to reduce the existing inequalities in energy use
e. Maximise satisfaction of demand for energy from indigenous resources

Medium-term

a. Initiate steps towards progressive substitution of petroleum products by coal, lignite, natural gas, and electricity so as to restrict the level of oil imports to the current level
b. Initiate action for the accelerated development of all renewable energy resources, especially exploitation of the available hydroelectricity potential
c. Promote programmes to achieve self-reliance in the energy sector
d. Promote R & D efforts towards decentralised energy technologies based on renewable resources
e. Initiate appropriate organizational changes for different energy sub-sectors consistent with the overall energy strategy

Long-term

a. Promote an energy supply system based largely on renewable sources of energy
b. Promote technologies for production, transportation, and end use of energy that are environmentally benign and cost efficient

The Eighth Plan programme for energy development was so oriented as to be consistent with this strategy (GOI 1992).

Despite the concerns expressed time and again, the demand for petroleum products has continued to rise rapidly, and the share of oil in the commercial energy supply has registered a steep increase during the last few decades. For example, the average annual growth rate of 6.9 per cent during the Seventh Plan was higher than the anticipated growth rate of 6.4 per cent. The increase in the indigenous availability of crude oil has not kept pace with the rapid increase in demand for petroleum products, leading to a steady increase in oil imports. The Eighth Plan was designed to achieve heavy dependence on coal and lignite and hydro resources. Energy conservation was a major thrust of this plan, which included financial arrangements such as the creation of a revolving fund, technical assistance, technology development, selective legislation, and development of institutional capabilities. Biomass is the main source of energy in the household sector, therefore the plan targetted improved cooking stoves.

It is felt, however, that India still needs to evolve a comprehensive energy plan taking into consideration the resource availability, technology, applicability, and environmental degradation. Realising this, the central government has placed special emphasis on, and given a boost to, the new and renewable energy sector, since these sources have practically inexhaustible potential and are environmentally benign. Renewable sources of energy are capable of solving the twin problems of energy supply in a decentralised manner and helping sustain a cleaner environment.

4.7.3 The New and Renewable Energy Sector

A new strategy and action plan has been formulated for the remaining period of the Eighth Plan. The new action plan envisages a four-fold increase in the target for renewable energy to 2,000MW compared with the original target of 500-600MW. The aim is to achieve the target through mobilisation of institutional financing (including bilateral and multilateral funding) and private sector investments stimulated through entrepreneural development and a package of incentives. Policy changes have been made in the fields of both solar photovoltaics and solar thermal systems to encourage market development and minimise direct subsidies. This opening up of the market, especially for solar photovoltaics, has resulted in greater competition, modernisation, and cost reduction besides encouraging genuine entrepreneurs. Rapid growth of the solar photovoltaic and solar hot water industries has started as a result of introduction of incentives and soft loans against the budget-driven subsidy programme. Policies have been pursued to encourage direct foreign investment and collaboration. Non-resident Indians (NRI) have shown interest and are in the process of setting up projects such as wind farms and solar plants, with a total power of 450MW, in the states of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, and Kerala.

Inter-agency and inter-ministerial contacts have been pursued to bring about greater involvement of user agencies. Initiatives have been taken to promote renewable energy applications in defence, railways, telecommunications, and similar establishments. Initiatives have also been taken to develop joint programmes with the

Rural electrification Corporation for promotion of decentralised renewable systems in villages that still do not receive electricity.

India is today recognised as one of the pioneer countries in the field of renewable energy. These forms of energy play a significant role in supplementing conventional power generation in an environmentally benign manner and, in particular, in meeting the needs of the household and industrial sectors. A three-fold strategy has been pursued by the Ministry for the promotion of new and renewable sources of energy (NRSE). This includes (a) providing budgetary resources from the government for demonstration projects; (b) extending institutional finance from the Indian Renewable energy development Agency (IREDA) and other financial institutions for commercially viable projects with private sector participation and external assistance from such bodies as the World Bank, the Global Environment Fund (GEF), and the Danish International Development Agency (DANIDA) and c) promoting private investment through fiscal incentives, tax holidays, depreciation allowances, facilities for wheeling and banking power for the grid, and remunerative prices for the power provided to the grid. The Ministry of Non-conventional Energy Sources (MNES) intends to promote a new community of 'energy entrepreneurs' whereas the government will act as the 'mission leader' giving a special focus and direction.

Organizational Restructuring of MNES

The Ministry's structure has been basically technology oriented. This was appropriate during the period when the technology for NRSE had to be developed, demonstrated, and proven. However, at the present stage of development the orientation needs to be towards markets, and it has become imperative to commercialise various programmes.

The MNES has been restructured accordingly and the administration reoriented so it can fulfill its new role of mission leader and create an environment in which the NRSE movement can be launched. The Ministry now has five major divisions: power generation from renewable energy, rural energy, urban waste conversion and other energy systems, new technologies, and planning and coordination. The Ministry has been augmenting its activities through a large network of NGOs, technical institutes, state government agencies, and local bodies working in the field of renewable energy and has thereby succeeded in generating a mass movement for the sector in the country.

The Small Hydropower Development Programme

MNES was originally responsible for the implementation of small hydropower projects up to three MW. This limit was raised recently to 15MW. The new strategy and action plan aims at achieving a goal of 600MW of energy power generation in the next three years through small hydropower projects, three times the target originally envisaged for the Eighth Five Year Plan. Around 2,000 potential sites with an estimated capacity of 5,000MW have been identified in the states of Uttar Pradesh, Arunachal, Orissa, Andhra Pradesh, Kerala, Madhya Pradesh, Himachal Pradesh, and Punjab. The target of 600MW is expected to cover almost 1,000 sites in different states. To encourage exploitation of this potential, the ministry has announced a composite scheme for survey and investigation, and for the preparation of Detailed Project Reports (DPR), 50 per cent of the cost of the latter being provided as a grant. Under the two schemes, 12 projects with a total of 25MW have been sanctioned for survey and investigation, 19 projects with a total of 31MW for DPR preparation, and 22 projects with a total of 26MW for actual implementation. It is anticipated that the potential of small hydropower projects (up to 15MW per site) in the country may exceed 10,000MW.

Portable Micro-hydel Sets

In view of the remoteness and lack of infrastructure and electricity grid in various areas, particularly the hills, an innovative scheme for providing 50 portable micro-hydel sets of up to 15kW in capacity each for local communities was also launched. A UNDP/GEF project on optimising the development of small hydel resources in the Himalayan and sub-Himalayan regions has been initiated with a UNDP contribution of US dollars 7.5 million and counterpart funding of IRs 22 crore (US dollars 6.9). Thirteen hill states will participate in the project under which a Master Plan will be evolved and twenty demonstration projects installed.

Joint Sector Companies

In addition to the private sector or SEB mode of project implementation, the concept of formation of a joint sector company in each state is also being promoted with private sector, state/SEB, and MNES/IREDA participation. This would enable turn-key survey, design, execution, and commissioning and remove the usual bottlenecks that result from the multiplicity of agencies involved in such things as land acquisition, statutory clearances, and grid connection. The concept has been welcomed by many states and the first joint sector company is likely to be set up in Uttarakhand. Other states are actively considering the proposal.

The Rural Energy Programme

Under the new strategy and action plan, it is envisaged that additional one million family-sized biogas plants will be installed during the Eighth Plan period, compared with the 0.75 million originally envisaged. Up to two million family-type biogas plants and 16.75 million improved cooking stoves have also already been installed.

The strategy for the universalisation of rural cooking energy programmes envisages covering 20-25 per cent of the potential beneficiaries by the end of the Eighth Plan.

The Integrated Rural Energy Programme

The Integrated Rural Energy Programme (IREP) was transferred to MNES from the Planning Commission with effect from 1 April, 1994. The IREP provides a comprehensive framework for macro-level planning of the energy requirements of rural areas. The programme is being implemented taking a block[12] as a unit and has been extended so far to 452 blocks. To enhance the effectiveness of the programme at field level, inputs from ongoing rural energy programmes are being harmonised and increased involvement and concentration of renewable energy programmes are being planned. The programme will be extended to 100 new blocks during the current year.

UNDP - GEF India Hilly Hydro Project

This project was being implemented by a Project Management Cell (PMC) established by MNES at the Tata Energy Research Institute (TERI) in Delhi. It became functional on the 16th December 1994. The total cost of the project is US$ 15 million spread over a 3.5 year period. The project has the following three main components: a) to develop a national strategy and a master plan with detailed investment proposals; b) to develop a package of commercially viable and environmentally sound technologies, after installation and commissioning of twenty demonstration units in various selected places; and c) to develop institutional and human resource capabilities from local to national level for the execution/implementation of the project.

IREDA: The Soft Loan Window of MNES

The main objective of the IREDA is to act as a catalyst for accelerating commercialisation of new and renewable sources of energy. IREDA has been assigned the main task of administering a revolving fund to promote, develop, and finance (on soft termis) NRSE technologies. The resource base of IREDA consists mainly of equity support from the Government of India, grants from foreign and international organizations, borrowing, and internal accruals. The authorised share capital is IRs 25[13] crore and the paid up share capital is IRS 24.30 crore. The authorised share capital is expected to be raised to IRs 100 crore in the near future. In addition, the

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[12] A block is the lowest development planning unit generaly consisting of 60-80 villages.

[13] A crore is 10 million.

Government of the Netherlands has already given a grant-in-aid of 17 million guilders[14] to IREDA to assist NRSE projects.

The World Bank has also agreed to provide 195 million US dollars, which includes a grant-in-aid component of 30 million US dollars to be contributed by the Global Environment Trust Fund and the Swiss Development Cooperation for financing projects to generate power through wind energy, small hydro, and solar photovoltaic schemes. IREDA has also signed an agreement with the Asian Development Bank to receive technical assistance of 354,000 US dollars.

4.8 Findings of the Study

There are considerable problems involved in trying to compile a clear picture of energy end use and supply in the Indian HKH region, for both conventional and non-conventional energy sources. Information on non-conventional energy sources, together with data on the installed electrical capacity and amount of coal, oil, and kerosene consumed, is only available at the state level and not at district level, at least not in a readily usable form. Renewable energy consumption patterns have been estimated for some blocks. The values are quite variable, and it is difficult to assess the reasons because: a) there is no information available on how the data was collected; b) there is confusion in the energy conversion units; c) the sampling basis is unclear; and d) it is not clear whether the data cover all strata of the population. In contrast, the demographic information has been very well compiled (for 1992) by the Centre for Monitoring the Indian Economy Private Limited. At government level the information is patchy. Information on end energy uses is not documented at all. There are not even any empirical studies on this issue. The information given in this paper is extrapolated using the census of 1991 and a few surveys conducted at the block level as a basis.

The task of establishing an energy data base in individual regions is a tedious one because of the lack of energy policy concentrating on such an exercise. The census undertaken at the national level gives the percentage of households using a certain type of fuel. Consumptions of commercial fuel, however, are only available at the state level. An attempt is then made to use these and extrapolate from some sample surveys of a few blocks to find the energy consumption patterns in individual regions, which then serve as the basis for *developing a database*. Detailed studies are needed, the results of which can be used for detailed planning.

Energy consumption patterns in the HKH region of India are changing rapidly. Although traditional fuels, such as fuelwood, dung, and agricultural residues, still

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14 There are 1.87 guilders to the U.S. dollar

dominate the energy scenario, particularly in the household sector, there has been a growing trend in the consumption of commercial energy, particularly LPG, petroleum products, and electricity. With a growth rate of more than seven per cent, there is a grave danger of an increased inability of the supply to meet the demand. Renewable forms of energy can be exploited to reduce this burden if a comprehensive plan is developed for each region. This requires a better energy data base at the decentralised level.

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Solar photovoltaic panel on the roof top of a monastery, Nubra Valley, Ladakh, India

Chapter 5

Pattern of Energy Use in Nepal

by

Kamal Banskota[15] and Bikash Sharma[16]

5.1 Introduction

5.1.1 General Situation

Nepal is a small land-locked country located between India and China, covering an area of 147,181sq.km. About 21 per cent of the country's total land area is cultivated, 42 per cent is under forest, 12 per cent is grassland, and the remaining 25 per cent is accounted for by other uses. Over 80 per cent of the country's land mass is rugged hill (65%) or mountain (18%) terrain. The hill region, sometimes called the middle mountains, is located in the middle part of the country and lies between altitudes of 610 and 4,877masl. Although this region has a relatively large area, only 10 per cent is suitable for cultivation. The altitude of the mountainous region varies from 4,877 to 8,848masl with the world's highest mountain, Mt. Everest, at the top. Only two per cent of this region is suitable for cultivation.

The 1991 census recorded a population of 18.4 million growing at the rate of 2.6 per cent per annum. About half the population lives in the Terai and the rest in the

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hill and mountain areas. According to the census, 70 per cent of the total population were of working age (14-59 years).

Because of its varied topography and elevation, the country has a wide range of climates. The following main types of climate can be recognised (MPFS 1989): a hot monsoon or subtropical climate in the *Terai* and Siwaliks (up to about 100m); a warm temperate monsoon climate in the lower middle mountains (up to 2,000m); a cool temperate monsoon climate in the higher middle mountains (up to about 3,000m); an alpine climate in the high mountains (up to about 4,000m); and a tundra type 'arctic' climate in the high Himalayas.

Precipitation varies from one place to another. The average annual rainfall is about 1,500mm but ranges from 250 to 4,500mm. The mean temperature for the country as a whole is around 15°C but varies considerably as a result of the topographical features. Generally, the temperature increases from north to south and rainfall decreases from east to west.

Nepal is drained by numerous rivers which can be broadly grouped into three types depending on their sources and discharge: a) the major rivers Mahakali, Karnali, Gandaki (Narayani), and Koshi that originate in the trans-Himalayan region and offer promising water sources for large-scale irrigation and hydropower development; b) the medium rivers Babai, West Rapti, Bagmati, Kamala, Kankai, and Mechi originating in the Mahabharat range or middle mountain region; and c) small rivers mostly originating from the Siwaliks and seasonal. In fact over 80 per cent of the country's land area is drained by three major river systems: the Koshi basin in the east, the Karnali basin in the west, and the Gandaki basin in central Nepal, all of which drain into the Ganges. Soil loss is becoming Nepal's single-most important resource conservation problem. Estimates indicate that Nepal is losing 240 million cubic metres of soil annually (HMG/ADB/FINNIDA 1988). About one third of the country's districts have marginal to very poor watershed conditions.

Forests form an integral part of the farming system and a central part of the natural resource base on which the rural production system and livelihoods of a vast majority of the Nepalese population depends. About 15 per cent of the GDP and more than 80 per cent of the country's energy needs are derived from this sector. National forests are also the main element of the National Parks and Wildlife Reserves. About 15 per cent of the total area of the country is in protected areas.

5.1.2 Energy Situation

Nepal's per capita final energy consumption (12.7 GJ) is one of the lowest in the world. Only four other countries in the world have a per capita consumption lower than Nepal (WECS 1994a). The preponderance of a rural sector characterised by a subsistence economy and low economic growth largely explains the low level of energy consumption. Evidence reveals a close association between economic development and per capita energy consumption[17]. Despite this low level of per capita energy consumption, the prevailing pattern of energy use and production indicate many elements of unsustainability. The energy problem in Nepal arises not from excessive reliance on non-renewable energy resources, but rather from the fact that one form of energy (fuelwood) is being consumed at an unsustainable rate, while the vast potential of other forms of renewable energy remains virtually unused.

Traditional energy forms predominate in the energy sector in Nepal. About 91 per cent of the total final energy consumption (260 million GJ) in 1994/95 was met by traditional forms of energy such as fuelwood (81%), agricultural residues (4%), and animal waste (6%), the rest came from commercial sources such as petroleum products (7%), coal (1%) and electricity (1%). There has been little change in energy transformation over the last decade. The share of traditional energy has declined only marginally, from about 95 per cent in 1984/85 to 91 per cent in 1994/95. The low level of commercial energy consumption in the country (about 9% of the total final energy use) is a clear manifestation of the very low level of industrial activities.

The main feature of the energy sector in Nepal is the growing imbalance between energy resource endowment and its current use. Heavy reliance on the dwindling forest resources to meet the growing energy needs despite abundant unexploited hydropower potential indicates a serious limitation to achieving the increase in the level of energy consumption necessary for higher economic growth and sustainable development. The present deficit in the fuelwood supply (6.6 million tonnes) is expected to continue given the excessive human and livestock population pressure on the accessible forests (Box 5.1). Estimates indicate that the deficit will be concentrated in the *Terai* and middle mountains, home to 85 per cent of the population (MPFS 1988; WECS 1994c).

The major characteristics of the energy scene are the dominance of the household/household sector over other sectors in total energy demand and the importance of biomass fuels in this sector's choice of energy. There are no readily available substitutes for biomass fuel in rural areas. Nor is there any widespread use of energy saving devices to increase the efficiency of biomass fuels. The prevailing pattern of

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17 Evidence indicates that energy has a determining influence on the level of development as measured by the Human Development Index (HDI) in the early stages of development. The influence of per capita energy demand on HDI, however, begins to decline at somewhere between 1,000 and 3,000kg of oil equivalent per capita per annum (43-129GJ). Above this level the HDI does not improve even if the energy consumption triples (Goldberg and Johonson 1995).

Box 5.1: The Degradation of the Resource Base

In the absence of feasible substitutes for fuelwood, rural households only have the choice between encroaching on accessible forest and making inter biomass fuel substitutions. But ppportunities for the latter are very limited. The heavy reliance on fuelwood implies that the pressure on accessible forest will continue, especially in the rural areas where there are no other renewable sources of energy available and it is more common to have a situation of open access to the forest. At the same time, the acute shortage of food and rampant poverty in these areas is forcing people to encroach on the forest to expand their agricultural land. Although the extensification pressure on forest is believed to have been limited in recent years with the closing of the land frontier, the pressure on forest near settlements has built up to a stage where a process of destruction of the biomass stock at the margin is becoming common in many parts of the country. As a result of lack of proper forest management, this destruction at the margin process is contributing to the deforestation process in the country.

Source : Banskota and Sharma (1997)

biomass energy utilisation is characterised by extensive production with inefficient and irrational supply management, diversion of crops and livestock residues from soil fertilization, and extremely inefficient combustion of biomass fuels. The country's grass biomass energy consumption actually reflects a much lower consumption of useful energy (energy efficiency-14%). This implies that large quantities of energy are being lost in the process of consumption (processing, conversion, and end-use technology) as a result of the poor quality of technologies and the energy mix. The complementary nature of the energy mix, especially in the rural household sector, indicates that there is limited scope for interfuel substitution. Biomass fuel is currently collected in the slack season (when there are fewer demands on people's time) at no cost other than the time and labour involved. Given the widespread unemployment, the opportunity cost of time for unskilled labour is lower than the price of fuelwood, thus biomass fuel will continue to dominate the rural energy scene for the foreseeable future.

5.2 The Energy Resource Base

Although the energy resource base in Nepal consists of biomass, hydroelectricity, petroleum products, natural gas, and coal reserves, biomass energy effectively dominates (WECS 1994b). Nepal has a huge potential for hydropower production, but currently this remains mostly untapped. Other commercial forms of energy are not known to exist in any significant amounts.

5.2.1 Biomass Energy

The theoretical estimated sustainable annual yield of fuelwood in Nepal is 25.8 million tonnes, or an average of 2.8 tonnes per ha of forest. However, only 42 per cent, or 10.8 million tonnes, of the theoretical sustainable supply is accessible.

Nepal relies mainly on biomass fuel as a result of the lack of development of other energy alternatives and the overall poor economic condition of the nation. Fuelwood is the main source of energy in Nepal and will continue to remain so for a long time. This is mainly forest-based energy. Nepal has 9.2 million hectares of potentially productive forests, shrub, and grassland, of which only 2.5 million hectares are considered to be accessible for fuelwood collection (WECS 1996). Forest, shrub, and grassland account for about 80 per cent of the accessible forest land area, 10 per cent is farmland, and another 10 per cent consists of non-cultivatable inclusions (NCI). In 1995 the sustainable fuelwood supply was estimated to be about 5.45 million tonnes of which 75 per cent came from government forest, shrub, and grassland, nine per cent from NCI, and the remainder from private farm land (WECS 1994c).

Forest resources are under increasing threat from the burgeoning human and livestock populations and their need to meet annual requirements for fuelwood, fodder, timber, and other minor forest products (Box 5.2). About 44,000 ha of forest area is believed to be degraded and deforested annually , while only about 4,000 hectares are reforested. Reforestation compensates for only nine per cent of the annual forest loss. At present there are about 268 million tonnes, 114 tonnes/ha of growing forest stock (Box 5.2).

Conversion of forest land for cultivation, high population growth, and a low level of development have all aggravated the pressure on forests throughout Nepal. Where forests are becoming relatively more scarce, people are relying increasingly on crop

Box 5.2: Depletion of Forest Stock

According to the Master Plan for the Forestry Sector (MPFS) the annual depletion of forest area during the period from 1979-85 was 3.9 per cent, a total of about 22,700 ha including unauthorised encroachment of an equal area for resettlement. A recent study by the Ministry of Forest and Soil Conservation indicated that the depletion of forest area was less in the mountains and Siwaliks than in the Terai. The annual depletion of 3.9 per cent during the period from 1979 -85 had decreased significantly to 1.3 per cent during the period from 1986-91.

residues and dung for energy. In 1994/95, the supply of crop residues in the country that could be used as energy was estimated to be 112.13 million tonnes (WECS 1994c; PEP 1995). Likewise the country has 4.8 million tonnes of animal dung annually potentially available as fuel.

5.2.2 Hydropower

The Karnali System in the west is by far the largest river system in Nepal with an estimated hydropower potential of 32,000MW (average run off of 18,000 cu. ft. per sec). The hydropower potential of the Gandaki (average run off 10,000 cu. ft.) and the Koshi (average run off 68,200 cu. ft.) rivers is estimated to be 21,000 and 22,000MW respectively. The total (theoretical) hydropower potential of Nepal's river systems is about 83,000MW, out of which only 25 per cent is potentially available for development (WECSa 1994; WECS 1996).

Hydropower utilisation is currently less than one per cent of the proven potential. The total installed hydroelectric generation capacity is 253MW, of which 248MW are hooked up to the national grid, and the remaining five MW are in isolated systems comprising 35 small/mini hydro plants serving remote areas of the country. The Marsyangdi scheme, with an installed capacity of 69MW, is the largest functioning hydroelectric project in Nepal (Shrestha 1996). The national grid represents the overall hydroelectric industry of Nepal as it accounts for almost 98 per cent of the capacity and 99 per cent of the energy supplied. Kathmandu alone consumes 45 per cent of the power from the national grid (Box 5.3). Losses and internal consumption in the grid system account for about 25 per cent of the total energy supplied.

Isolated supply systems are managed by both the public and private sectors and independent power producers. At present there are 35 small/mini hydroelectric plants with capacities ranging from 20 to 2,000kW in operation in remote areas of

Box 5.3: Access to Electricity

About 12 per cent of the population had access to electricity by 1996, compared to nine per cent in 1992 (an average growth rate of six per cent per annum from 1991-1996). The population covered by the private micro-hydro plants is estimated to be between 110 and 170 thousand. About 89 per cent of the urban and 4.5 per cent of the rural population has electricity (Shrestha 1996).

the country. From 1986 onwards, the number of micro <100kW hydro plants installed in accessible areas of the country declined. Only 30 private micro-hydro plants were constructed in 1991 compared to 99 in 1984/85.

Supply constraint is already a major problem for electricity, which is apparent in the frequency of 'load shedding' (planned power cuts) in different parts of the country. Load shedding is the result of high peak hour demand, and could be minimised if demand could be spread out. Currently demand estimations are confined to those areas covered by the transmission lines. There is still no comprehensive demand estimate available for the whole of Nepal (Box 5.4).

Box 5.4: The Growing Importance of Hydropower

Hydropower contributed about one per cent of the total final energy used in 1995, up from 0.3 per cent in 1980/81. Growth in non-agricultural GDP is positively related to growth in electricity consumption (r^2=0.835). A one per cent growth in non-agricultural GDP is associated with an increase in electricity demand of about 1.3 per cent. This highlights the importance of electricity in overall economic development (WECS 1994d).

5.2.3 Petroleum, Natural Gas, and Coal

So far no proven reserves of petroleum suitable for commercial exploitation have been found in Nepal. Thus all petroleum products consumed in Nepal are imported in refined form for direct consumption. The alternative energy source, natural gas, has also not been discovered as yet in any significant amount. Some exploration has been done in the Kathmandu Valley. Three potential sites for gas have been identified in the Teku-Tripureswor (Pachali), Koteswor and Tinkune, and Manahra-Emadol areas. Proven reserves have only been identified in the Teku-Tripureswor area (47.6 million m^3.). The two other sites are only listed as 'possibilities'. The known reserves are not sufficient to last for more than a few decades. Coal is currently among the cheapest sources of energy known to man. Two deposits in Nepal are believed to have some economic significance, one in Kathmandu and one in Dang. Even these deposits, however, are believed to be insignificant in terms of the energy demand (WECS 1994b).

5.3 Renewable Energy Technologies

The most important renewable energy technologies[18] in the context of Nepal are related to micro-hydropower, biomass energy (biogas, briquettes, improved cooking stoves), solar energy (solar water heaters, dryers, cookers, generators and pumps) and wind energy (wind turbines, windmills). Renewable energy technologies only received importance in the Eighth Five Year Plan (1992-97). This plan provides detailed policy descriptions and programmes, including the provision for an institutional set-up for the development of renewable energy in Nepal. Despite relatively attractive economic gains, the development of renewable energy technology in the overall energy scenario is still far from satisfactory as a result of a number of issues that have emerged in relation to its development (WECS 1994e). The main issues are:

- social issues related primarily to non-acceptance of the technology;
- planning and policy issues dealing mainly with the lack of willingness at the policy level;
- institutional issues dealing with the non-existence of responsible coordinating bodies;
- financial issues dealing with high initial investment costs;
- technical issues; and
- managerial and marketing aspects.

Box 5.5 summarises the main problems and issues associated with different renewable energy technologies.

5.3.1 Micro-hydropower

Various kinds of micro-hydro technologies such as propeller turbines, cross flow turbines, Pelton wheels, multipurpose power units (MPPU), peltric sets, and improvements in traditional ghatta (water wheels) better system efficiency have been developed in the past to tap water resources more effectively. A total of 947 micro-hydropower turbines with a total power of 8.6MW have been manufactured and installed in Nepal. They are mainly used for agro-processing activities, and electricity generation (311 units installed with 2.65MW capacity) (WECS 1994f; Shrestha and Amatya 1998).

The distribution of micro-hydro units is influenced, among other things, by proximity to the manufacturer, the extent of development of the region, donor support,

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* Alternative energy technology is synonymous with new, renewable, and non conventional forms of energy. Sun, air, water, and biomass are the main sources of renewable energy

Box 5.5: Major Issues and Constraints in the Development and Promotion of Renewable Energy Technologies

RETs	Technical	Financial	Policy and Institutional
Micro-hydropower (MHP)	• Most mill owners are not trained in management • O&M Operation and Management ignored • Management aspect neglected in feasibility studies The cost of feasibility studies borne by manufacturers, studies are biased leading to various technical and socioeconomic problems	• The high cost of the plants and low load factors (below 50%) of the plants make the projects economically unviable • Lack of data is another constraint	• Lack of a government policy for subsidising MHP has hindered private investment • Investment allocated to this sector is too meagre to have any impact • Lack of systematic monitoring and evaluation because of lack of inter institutional linkages and coordination • Priority given to the projects themselves rather than to developmental activities for end-use devices
Biogas	• Quality of construction material and monitoring differ among the companies installing such plants • Poor performance as a result of inferior construction material, selection of wrong sized, and negligence in construction and operation • The main problem in family size plants is low gas yield during the winter and rainy seasons. The problems for community-sized plants relate to ineffective management, sharing of benefits, and distribution of slurry among the community members • Lack of trained manpower to supervise, maintain, and repair biogas digestors	• Although biogas production is superior to direct burning of cake (dung) in terms of energy utilisation (thermal efficiency of 60 per cent against 11 per cent for dung cake), it can only be profitable and attractive for marginal farmers if a subsidy is provided • Biogas production will become more popular as fuelwood becomes scarcer	• Institutional gaps are the main bottleneck to promoting and carrying out the government policy and programme smoothly • Compared to the Gobar Gas Company (GGC), the newly formed private companies do not have enough experience to guarantee quality. More vigorous training is needed at all levels • There is no research and development (R&D) institute to concentrate on developing less expensive biogas plants • There is a need for a competent biogas development and promotion unit with full authority for overall policy development, planning, monitoring, evaluation, quality control, research, and training and able to establish a functional linkage between the government and existing organizations

Box 5.5 Cont..........

RETs	Technical	Financial	Policy and Institutional
Improved cooking stoves (ICS)	• Holes for pots are too small to accommodate the large pots used in many households • The baffle is too small to achieve good heat transfer • ICS cannot provide both space heating and cooking, especially important in the higher hills and mountains • ICS cannot handle agricultural biomass and industrial residues • Inserts are too heavy and too fragile for widespread dissemination in Nepal • Breakage rates are high and it is difficult to replace the broken parts of stoves • Lack of quality control at production sites results in the production of low quality stoves	• ICS programmes are largely dependent on funding from external donors rather than on mobilisation of internal funds (weak financial sustain ability)	• No national policy framework and programme direction integrating ICS as a multisectoral component • No institutions with the overall responsibility for the development and promotion of ICS • Lack of extensive and continuous research • Lack of interaction between researchers, extension agencies, and policy planners, as well as between producers and end users • Overemphasis on achieving dissemination targets with little attention given to extension and monitoring. No formation of a self-sustainable base of ICS users • The past approach has led people to expect free supply, installation, maintenance, and repair of ICS, and this has a negative impact on potential buyers
Solar	• Lack of adequate knowledge, information, and technical know-how among the manufacturers is a major problem for solar water heaters • Leakage problems in storage tanks and hot water pipelines is a problem for industrial solar heaters • Solar cookers cannot be used for frying, cooking time is longer, and their use is limited to times of good sunshine. Lack of a storage system is another problem limiting their widespread promotion and dissemination • Frequent breakdown of electrical components is a major problem in PV electricity generation	• Although the financial performance of solar thermal devices appears sound, in practice the financial aspect of PV systems has been found to be negative • Solar dryers have high capital investment costs	• Strong need for institutions to enforce standards and provide quality control for manufacturers, especially in the case of solar water heating systems • Need for multidisciplinary knowledge of science and technology related to solar dryers • Solar cookers are not suited to local cooking practices • Lack of solar radiation, transmission losses, and consumer over-demand are the major obstacles to full capacity operation of PV power plants

and the availability of electricity from NEA. From 1986 onwards the number of micro-hydro plants being installed within accessible areas of the country declined.

At present, the NEA has no plans to construct new hydropower plants in the micro-range and thus rural areas, especially in the hills and mountains, can only receive electricity through private utility micro-hydro plants. There is a subsidy of 50 to 75 per cent on the electrification component for private micro-hydropower generation.

Recently, cooking by electricity has also become popular as a result of the efforts of micro-hydropower promoters. Low wattage cookers (*bijuli dekchi*) are in use in different parts of the country. This has resulted in some substitution of firewood (WECS 1994f; Banskota and Sharma 1996). Other uses of micro-hydropower include beating and digesting pulp and drying paper.

5.3.2 Solar Energy Technology

Solar energy has been used traditionally for drying such things as crops, clothes, fuelwood, and crop residues. The solar energy potential in Nepal is estimated to be about 26 million MW. Currently there are two types of solar energy technology in the country: solar thermal systems and solar photo voltaic (PV) systems.

Solar water heaters and solar dryers are the two main types of solar thermal device. Of these, solar water heaters[19] have the widest distribution in Nepal, with 30 to 35 firms, mainly concentrated in Kathmandu, manufacturing them. The present installed capacity is estimated to be around 300,000 litres per day (WECS,1996). These heaters are suitable for use throughout the country except in those regions that have long and harsh winters where the temperature falls below freezing point. However, because of the high cost (Rs 23,000 for a 200 litre system), this technology is too expensive for most people.

About 15 different types of solar dryer have been used in the country for drying spices, fruits, vegetables, and herbs. The fabrication of solar dryers is simple and they can be constructed using locally available materials. However, solar dryers have not been able to establish their credibility because of the high capital investment required and the lack of specific designs for different products and quantities. Such designs require a multi-disciplinary knowledge of science and technology related to drying.

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19 Currently, two kinds of solar water heaters are being marketed, integrated tank systems and circulation systems. In the industrial sector, thermo-syphon solar water heaters with separate storage tanks are generally used, while, in the household sector, the most commonly used system is a complete one with attached storage tank.

Solar cookers were introduced by the Research Centre for Applied Science and Technology (RECAST) in 1977 as parboiling cookers. Because of their high cost, this technology has not become popular. Although various types of solar cooker have been developed to reduce cost, efforts to improve the efficiency of solar cookers have not been encouraging.

The solar PV system is another technology which converts solar energy directly into electricity. The NEA has carried out solar photovoltaic based rural electrification in different locations with an installed peak power of 130kW. Forty-three airports in the country use solar PV energy. Nepal Telecommunications has also installed solar PV sets in 16 locations. The cost of a centralized solar PV-based power system is high, however, compared to electricity generation by smaller micro-hydropower units.

Lately, private entrepreneurs and non-governmental organizations (NGOs) have been showing interest in the dissemination of solar PV home lighting systems. The cost of a SPV home system (30-35 W) ranges from NRs 30,000 to NRs 35,000 depending on the system's capabilities and facilities. These home systems are gaining popularity in some areas of Nepal (Shrestha and Bajracharya 1998).

5.3.3 Biogas Technology

Biogas technology is considered to be one of the most promising and sustainable sources of renewable energy in Nepal (Box 5.6). At present most biogas plants are in the Terai, but they are gaining in popularity in the hill regions as well. The mountain region is unfavourable for biogas production because of the cold climate. More than 32,000 biogas plants of different sizes have been constructed so far in the country, although there is scope for the installation of an estimated 1.3 million units

Box 5.6: Constraints to the Wider Use of Biogas Technology

Despite biogas technology being fairly successful at present, a number of technical and institutional problems have emerged that will greatly retard diffusion of this technology. Uniformity or standardisation of design, installation, construction materials, or supply of accessories has not yet been achieved. There is still no competent biogas development and promotion unit in the country. Costs are escalating and beyond the affordable limit of poor households. The interaction between designers and end users is poor, which does not help to improve the design.

(WECS 1996; Gongal and Shrestha 1998). If all the available dung were to be used for biogas[20] the potential biogas production would be around 12,000 million m^3 per year, which is equivalent to 29 million GJ (about 10% of the present energy consumption). Use of this dung would not affect agricultural productivity (WECS 1996).

The current state of development of biogas in Nepal is largely the result of incentives provided by His Majesty's Government (HMG/N). A plan for the installation of biogas plants was first incorporated in the Seventh Five Year Plan (1985-90). During this plan period both capital and interest subsidies for the biogas programme were provided by the government through the Agricultural Development Bank. This subsidy programme is now being continued with the assistance of the Government of the Netherlands.

5.3.4 Improved Cooking Stoves (ICS)

Improved cooking stoves have the potential to save the fuelwood used for household cooking. About 11 million tonnes of fuelwood are burnt annually for cooking alone. Theoretically, it is possible to reduce fuelwood consumption for cooking by 50 per cent. ICS have an efficiency factor in the range of 15 to 30 per cent, whereas the efficiency of traditional mud stoves varies from three to 15 per cent. There are various types of ICS and the efficiency of these stoves varies (Bajracharya and Gongal 1998). The amount of fuelwood saved depends among other things on the type of ICS, the condition of the fuelwood, the type and amount of food prepared, and the type of pots used for cooking. Even with a low performance of 11 per cent fuelwood savings, estimates indicate that one ICS can save an average of one tonne of fuelwood annually.

5.3.5 Wind Power

This technology is still in its initial experiment phase. A wind power system was installed in Kagbeni to generate about 20kW of electrical power (annual energy of 50MWh) but was damaged as a result of the poor design. The high installation cost (about US $6,800 per kWh) did not justify further development (WECS 1994e).

5.3.6 Manufacturing Capability of Renewable Energy Technologies

There are altogether 12 turbine manufacturing units, mostly located in the Kathmandu Valley and Butwal, with a combined production capacity of 200 water turbines per year. Nine companies are active in micro-hydropower development

[20] The total dry dung produced in Nepal is about 11 million tonnes per year.

(dLA and CRT 1997). All the companies, with the exception of BEW, NHEC, and BYS, are confined to manufacturing turbines below 100kW in capacity. The three big companies can manufacture turbines with capacities of up to 250kW. The growth in manufacturing of micro-hydropower units in the country has been affected by a decline in the demand for turbines.

Micro-hydropower manufacturers carry out both design and installation. Micro-hydropower development is based primarily on local expertise in design and manufacturing capabilities. Although some micro-hydropower manufacturers have started to export plants to India, Indonesia, and Malaysia, Nepal has to depend on its own technological capability for micro-hydro development as a result of the lack of well established international markets for micro-hydropower equipment.

The major source of raw materials for micro-hydropower manufacturers is India. In addition, big companies like BEW and NHEC import raw material directly from Norway and other overseas countries. The total manpower employed by micro-hydro manufacturers is 438, with BEW and NHEC the biggest employers (194 people). This indicates how small this sector is, despite the numerous producers.

Various national and international institutions have been involved in the development, promotion, and implementation of biogas technology in the country. The Gobar Gas Company is the leading institution in this sector. Established in 1978 with financial support from the United Mission to Nepal (UMN), ADB/N, and the Timber Corporation of Nepal (TCN), the GGC introduced biogas technology in more than 50 districts in 1992 and has trained hundreds of people to construct and manage biogas plants. Other institutions involved in this sector are the UMN, the Asian Development Bank, the United Nations International Children's Fund (UNICEF), United States Agency for International Development (USAID), the Food and Agriculture Organization (FAO), the United Nations Capital Development Fund (UNCDF), the Nepal Office of the Netherlands Development Organization (SNV-Nepal), and more than 40 private companies. Despite various agencies involved in this sector, there has been little support for R&D. Moreover, effective monitoring at the national level has been lacking.

Various government, semi-government, donor, and private organizations and research institutions are involved in the development and promotion of ICS in the country. However, this energy technology is beset with institutional constraints. These include the lack of extensive and continuous research, the fact that interactions among researchers, policy planners, and extension agencies are negligible; and that there is no intensive interaction between designers and end users to solve the long-standing problems of discontinuation of this technology because the designs are not suitable for local conditions.

There is no effective institutional arrangement for the production and promotion of solar energy devices. Individuals and institutions work independently. This has resulted in a lack of uniformity in design and quality of the products manufactured and hence in their end-use efficiencies.

Three private companies have started manufacturing, installing, promoting, and servicing household and community sized solar PV system packages commercially. Other institutions such as WECS, RECAST, the Royal Nepal Academy for Science and Technology (RONAST), NEA, the Centre for Rural Technology (CRT), and the Centre for Renewable energy (CRE) are also involved in promoting solar technologies.

Some of the institutional constraints to the expanded use of RETs are worth mentioning. First, there is a lack of coordination between researchers, manufacturers, and potential users, and current energy polices are biased against renewable energy. Second, until now there has been no single government agency responsible for overall coordination of the activities related to the development of renewable energy. The recently created Alternative Energy Promotion Centre (AEPC) needs to be strengthened in terms of manpower and funding to act as a facilitator for the promotion of RETs. Finally, the traditional approach to the management and planning of energy, which has been sectoral and focussed on forestry, agriculture, and industry, has not been effective.

5.4 The Energy Consumption Pattern

The energy sector in Nepal is characterised by a heavy reliance on traditional energy sources, particularly fuelwood which mostly comes from the forests. Despite the declining share of fuelwood in total energy consumption, the relative share of traditional energy has remained almost stagnant over the past decade as the use of animal dung and agricultural residues for fuel has increased. Consumption of commercial energy in the country is growing at a faster rate than consumption of traditional energy, although the consumption level is still very low as a result of the country's lack of industrialisation and low level of development. The total final energy consumption in the FY 1994/95 was estimated to be 260 million GJ, 90 per cent of which was consumed in the household sector (Table 5.1). More than 87 per cent of the total commercial energy consumed is met through imports. These imports require almost 35 per cent of the total foreign exchange earning from exports.

5.4.1 Final Energy

<u>Household Sector</u>

The rural and urban residential sectors are estimated to have consumed about 219 and 15 million GJ, respectively, in the FY 1994/5. Biomass fuels dominate in

Table 5.1: Final Energy Consumption Pattern in Nepal, FY 1994/95

Units: Thousand GJ

Description	Household		Commer-cial	Indus-trial	Agricul-ture	Trans-port	Total Energy	
	Rural	Urban						(%)
Total Biomass	215,875	12,910	778	7,482	0	0	237,045	92
- Fuelwood	192,152	10,154	773	7,177	0	0	210,244	81
- Agricultural Residues	8,186	1,266	5	305	0	0	9,762	4
- Animal Dung	15,537	1,490	0	0	0	0	17,026	7
Commercial	3,241	2,450	2,732	4,996	2,036	6,649	22,104	8
- Coal/Coke	11	3	286	2,523	0	16	2,840	1
- Petroleum Fuels	2,974	1,590	2,043	1,292	1,948	6,627	16,474	6
- Electricity	256	857	403	1,181	87	6	2,790	1
Total Energy	219,116	15,361	3,511	12,478	2,036	6,649	259,151	100
(%)	84	6	1	5	1	3	100	
Total Population (Thousands)							20,363	
- Rural							18,095	
- Urban							2,268	

Source: Study Estimates

both household sectors (comprising 98% of the total energy consumed in rural households and 84 per cent of that consumed in urban households). Kerosene is the main commercial fuel used by both urban and rural households. The bulk of the energy is used for cooking (65% in urban and 75% in rural households). In rural areas, other end-use activities are space and water heating (9.5%), agro-processing (3.5%), and lighting (1%).

Fuelwood meets the bulk of the energy demand in all three regions - mountain areas (98%), hills (89%), and the *Terai* (81%). The lower value in the *Terai* reflects a gradual transition from fuelwood to other sources of biomass fuel. Estimates of the proportion of total final energy used for cooking give 72 per cent in the *Terai*, 90 per cent in the hills, and 65 per cent in the mountains. Rural households in the mountain region use 11 per cent of their annual energy requirement for space heating, compared to six per cent in the hills and eight per cent in the *Terai*. Urban households in the hills use about 25 per cent of their final energy requirements for boiling water, for electrical appliances and for lighting, compared to five per cent in the *Terai*.

Commercial Sector

This sector consumed 3.5 million GJ of final energy in FY 1994/5. Kerosene (47%) ranks the first in terms of utilisation followed by biomass fuel (23%), electricity (11.5%) and coal (8%). LPG and other oil products contribute less than nine per cent of the total energy consumed in this sector. The share of fuelwood in the total is declining. Over 83 per cent of total final energy consumed in this sector was required for cooking, nine per cent for lighting, 6 per cent for space heating and boiling water, and the rest for other purposes.

Industrial Sector

The industrial sector accounts for about five per cent of the total energy consumption in the country. Fuelwood is still the dominant fuel consumed by this sector (57%), and the amount used has been growing at about seven per cent per annum over the last decade. Coal ranks second (20%) followed by petroleum fuels (10%), particularly diesel, and electricity (9%). The brick and tile industries (non-metallic mineral product-related industries) need fuelwood and coal, whereas petroleum fuels are used heavily in food and beverage industries. More than 50 per cent of the final energy consumed in the industrial sector is used for boiling, 23 per cent for motive power, and 24 per cent for process heating.

Transport Sector

The transport sector is estimated to have consumed 6.6 million GJ of energy in the FY 1994/5, nearly three per cent of the total energy consumption in the country. Diesel alone accounted for about 69 per cent of the total energy consumed, motor spirit (petrol) and aviation fuel for 31 per cent, and coal and electricity for less than one per cent. Road transport accounts for 85 per cent of the total energy consumed by this sector, the remaining 16 per cent is used in aviation. There has been a continuous high growth of all types of fuel consumption for road transport, mainly as a result of the extension of the road network and the increase in traffic flow.

Agricultural Sector

Energy consumption in the agricultural sector is very low (2 million GJ excluding energy from animate energy [musclepower of humans and animals]) accounting for less than one per cent of the total energy consumption in the country. Pumpset engines (internal combustion engines of 1-10 horsepower) and tractors accounted for 49 and 48 per cent respectively of the total energy consumed in the agricultural sector in 1995. Diesel was the main source of the energy consumed (95%), followed by electricity (5%).

5.4.2 Useful Energy Consumption Pattern

The pattern of consumption of useful energy in various demand sectors by end uses and fuel types was estimated using the Reference Energy System (RES)[21]. The results are shown in Table 5.2. The useful energy consumptions were derived using the national-level energy efficiency parameters (end use efficiency matrix) reported in the Perspective Energy plans (PEP) for each energy consuming sector[22].

Household Sector

Rural areas The total consumption of useful energy in this sector in the FY 1994/95 was estimated to be 31.4 million GJ, about 14 per cent of the total final energy consumption. About 46 per cent of the useful energy required was for space heating, 39 per cent for cooking, and the rest for boiling water and agro-processing. Fuelwood contributed about 89 per cent of the total useful energy requirement, followed by agricultural residues (4%), dung (6%), and kerosene (1%).

The useful energy required for cooking constitutes only 8.5 per cent of the final energy used for cooking, indicating a large energy loss (low efficiency) in this activity. This compares with the 82 per cent efficiency recorded for electrical appliances and space heating. The energy efficiency varies greatly across the ecological regions depending on both the end-use devices and the type of fuel used.

21 The RES highlights the comparative efficiency of various end use devices, even though different types of fuels are converted, transported, and consumed to produce energy services. There are several possible structures for the RES. The fuel cycle approach is one in which the RES can be structured to trace energy flow from sources to services. For example, primary energy provided by the energy source is first converted into secondary energy through process technology. Conversion technology converts the secondary energy into final energy; followed by conversion of final energy into useful energy in end-use devices, which is what really counts to the consumer and is of primary concern for energy demand analysis and planning.

22 See Banskota and Sharma (1997) for details on the end use efficiency matrix used for deriving useful energy for different sectors.

Table 5.2: Useful Energy Consumption Pattern in Nepal, FY 1994/95

Units: Thousand GJ

Description	Fuel-wood	Agric. Res.	Animal Dung	Total	Coal/ Coke	Pet-roleum	Electri-city	Commer -cial	Total	Energy (%)
Rural Household	27,822	1,384	1,815	31,021	3	338	56	397	31,418	100
- Cooking	10,686	333	799	11,818	3	294	3	300	12,118	39
- Space Heating and Cooling	12,766	883	842	14,491	0	23	2	24	14,516	46
- Boiling Water	292	11	6	309	0	17	0	17	326	1
- Lighting/Elec. Appl.	0	0	0	0	0	4	51	55	55	<1
- Agroprocessing	587	16	34	637	0	0	0	0	637	2
- Other	3,491	141	134	3,766	0	0	0	0	3,766	12
Per cent of total (%)	89	4	6	99	<1	1	<1	1	100	
Urban Household	1,540	189	210	1,939	<1	685	318	1,003	2,942	100
- Cooking	1,010	104	128	1,242	<1	539	38	577	1,819	62
- Space Heating and Cooling	318	64	72	454	0	11	24	35	489	17
- Boiling Water	46	6	0	52	0	135	4	139	191	6
- Lighting/ Elec. Appl.	0	0	0	0	0	0	252	252	252	9
- Agroprocessing	20	3	0	23	0	0	0	0	23	<1
- Other	146	12	10	168	0	0	0	0	168	6
Per cent of total (%)	52	6	7	65	<1	23	11	35	100	
Commercial	153	0	0	153	71	886	356	1,313	1,466	100
- Cooking	147	0	0	147	71	836	24	931	1,078	74
- Space Heating and Cooling	<1	0	0	<1	0	29	91	120	121	8
- Boiling Water	5	0	0	5	0	19	2	21	26	2
- Lighting/Elec. Appl.	0	0	0	0	0	2	239	241	241	16
- Other	0	0	0	0	0	0	0	0	0	0
Per cent of total (%)	10	0	0	10	5	60	24	90	100	

Table 5.2 Cont..........

Description	Fuel-wood	Agric. Res.	Animal Dung	Total	Coal/ Coke	Pet-roleum	Electri-city	Commer-cial	Total	Energy (%)
Industrial	2,713	80	0	2,793	1,282	497	987	2,766	5,559	100
- Motive Power	0	0	0	0	0	290	844	1,134	1,134	20
- Boilers	2,337	49	0	2,386	1,117	190	0	1,307	3,693	66
- Process Heat	373	31	0	404	159	4	36	199	603	11
- Lighting	0	0	0	0	0	2	99	101	101	2
- Other	3	0	0	3	6	11	8	25	28	<1
Per cent of total (%)	49	1	0	50	23	9	18	50	100	
Agricultural	0	0	0	0	0	535	74	609	609	100
- Pumpsets	0	0	0	0	0	247	74	321	321	53
- Tractors	0	0	0	0	0	288	0	288	288	47
Per cent of total (%)	0	0	0	0	0	88	12	100	100	
Transport	0	0	0	0	3	2,650	5	2,658	2,658	100
- Road	0	0	0	0	0	2,166	0	2,166	2,166	81
- Aviation	0	0	0	0	0	484	0	484	484	18
- Other	0	0	0	0	3	0	5	8	8	<1
Per cent of total (%)	0	0	0	0	<1	100	<1	100	100	
TOTAL	**32,228**	**1,653**	**2,025**	**35,906**	**1,359**	**5,591**	**1,796**	**8,746**	**44,652**	
(per cent)	72	4	5	81	3	12	4	19	100	
Per cent efficiency (%)	15	17	12	15	48	34	64	40	17	

Elec. Appl. = Electrical Appliances
Source: Study Estimates

Urban areas In the urban household sector, almost 62 per cent of the useful energy required was used for cooking, 17 per cent for space heating, seven per cent each for boiling water and electrical appliances, and the rest for lighting and motive power. Almost two thirds of the useful energy requirement in the urban household sector was met by biomass fuels, while the remaining 34 per cent was met by conventional commercial energy sources.

Regional Variation in Energy Efficiency Fuelwood is used relatively more efficiently by mountain households, whereas other biomass fuels are used more efficiently in the hills and mountains. The overall energy efficiency is relatively higher in urban areas than in the Terai. The efficiency of LPG is amongst the highest of all fuel types in all regions. Coal briquette ranks second to LPG in terms of efficiency in both the rural hill, and rural and urban Terai areas, while electricity and kerosene rank second in the urban hill areas. The end-use efficiency in all ecological regions is highest for space heating and electrical appliances. The end-use efficiency for cooking purposes is low in all regions with the exception of the urban hills where efficient energy use is about 26 per cent of the total final energy used.

Commercial Sector

The total quantity of useful energy consumed in the commercial sector in the FY 1994/95 was estimated to be 1.47 million GJ, about 42 per cent of the total final energy consumed. About 75 per cent of the useful energy requirement was met by kerosene (50%) and electricity (24%), while the remaining 25 per cent was contributed by fuelwood (10%), coal (5%), and LPG (10%). Almost 74 per cent of the useful energy was used for cooking, followed by 15 per cent for lighting and the rest for heating and cooling (6.5%), boiling water, and motive power. The efficiency of these end-use activities varies from 37 per cent for cooking and heating water to as high as 90 per cent for space cooling. In terms of fuel type, the estimated efficiency is amongst the highest for electricity (88%) and lowest for fuelwood (20%).

Industrial Sector

The total useful energy consumption in the industrial sector in the FY 1994/95 was estimated to be 5.6 million GJ, about 44 per cent of the total primary energy consumed by this sector. About 50 per cent of the useful energy required in this sector was met by traditional fuels, mainly firewood, while the remaining 50 per cent was contributed by electricity (18%), coal (23%), and petroleum fuels (9%). Over 65 per cent of the useful energy required in this sector was for boiling purposes, followed by 20 per cent for motive power and the rest for process heat (11%), lighting (2%), and motive power. The efficiency of these end use activities varies from 17 per cent for process heat to as high as 58 per cent for motive power. The estimated efficiency is highest for electricity (83%) and lowest for kerosene (3%).

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Agricultural Sector

In the FY 1994/95 the useful energy consumption in the agricultural sector accounted for less than two per cent of the total useful energy consumed in the country and was roughly 30 per cent of the total final energy consumed by this sector. Nearly 88 per cent of the useful energy requirement was met by diesel and the remainder by electricity. Over 47 per cent of the useful energy used in this sector was for tractors and the rest for pumpset engines. Electric pumpsets are the most energy efficient (85%) end-use devices when compared to IC-engine pumpsets (25%) and tractors (30%).

Transport Sector

The total useful energy consumption in the transport sector in the FY 1994/95 was estimated to be 2.7 million GJ, about 40 per cent of the total final energy consumed. Over 81 per cent of the useful energy was used for road transport, followed by 18 per cent for Aviation Turbine Fuel (ATF) aviation and the rest for other modes of transport such as railways, ropeways, and trolley busses. About 68 per cent of the useful energy requirement was met by diesel fuel, while the remaining 32 per cent was met by aviation fuel (18%) and motor spirit (petrol) (13%). The energy use efficiency of the transport activities varies from 20 per cent for road transport to as high as 80 per cent for ropeways.

5.5 The Structure of the Energy Market and Price Distortions

Nepal's energy sector has some peculiar characteristics that have a direct bearing on the structure of the energy market and price distortions. First, most energy sources (88%) in Nepal are not traded and hence do not pass through the cash economy. Second, the share of commercial energy in the import bill, which has to be met from foreign exchange reserves, has remained dominant despite the low proportion of commercial energy in the total energy consumed. Third, transmission and distribution of power in Nepal is quite expensive as a result of the small size of the demand centres and their scattered positions. Finally, the use of existing energy resources is grossly inefficient, partly as a result of price distortions.

The market price of energy does not reflect the true economic cost of supplying the energy. Some energy types such as rural electricity are underpriced, others are overpriced. This results in inefficient use of existing energy resources. Currently, the main price distortions in the market are as follow (dLA 1994).

- The existing price structure provides no incentives for sustainable production.
- The existing price structure and factors such as agricultural subsidies encour-

age economic inefficiency and overutilisation of substitute fuels such as petroleum products.

- Petroleum products are sold at cost price whereas light diesel oil (LDO) is heavily taxed, and this has led to excessive use of diesel in industrial applications.
- Coal prices are slightly higher than the economic cost as a result of technical inefficiencies.
- There is an *ad hoc* pricing mechanism.

5.5.1 Energy Prices and Pricing Mechanisms

Most fuelwood is not subject to market transaction. The price of imported commercial fuels, including LPG, are fixed by the government. The pricing strategy of the government is based on the principle of providing energy at a low cost to the general public. Imported commercial fuels are generally subsidised and distributed through a network of dealers for final consumption.

Fuelwood Prices

Since the closure of the Timber Corporation of Nepal (TCN) depots, fuelwood marketing has been carried out by private depots and dealers. The TCN price for fuelwood is determined by the transport distance from the harvesting point to the urban depot. The supply of fuelwood from TCN depots is too low to have had much impact on fuelwood prices.

Petroleum Product Prices

Petroleum product pricing is based on border costs plus other costs such as taxes and the cost recovery component of things such as administration, transport, dealer's commission, and stock losses. HMG fixes the price of motor spirit (MS), high speed diesel oil (HSDO), and kerosene (SKO). The prices of other products are fixed by the Nepal Oil Corporation board.

Coal Prices

Nepal Coal Ltd. (NCL) is the sole importer of coal. Private companies are also allowed to import coal at a five per cent dealer commission. The coal price in Nepal is determined by Indian pricing policy. The price of coal reflects its cost of delivery to the consumption point and is not subsidised.

Electricity Prices

Until the commissioning of the Electricity Tariff Fixation Commission, the electricity tariff was regulated by HMG/N at the cabinet level and based on the recommendations of the NEA board. The government continues to subsidise electricity for household and industrial users. Electricity prices have always been lower than the long-term marginal cost of supply. Currently, electricity pricing is calculated on the basis of WB/International Development Aid (IDA) financial covenants[23]. Since the FY 1991, the tariff has been revised five times and, during this period, the tariff increased at an annual rate of 28 per cent, almost five times the local currency escalation (6%). The payments obtained from household, industrial, commercial and non-commercial customers have increased between three and seven times more than the growth in consumption by each group.

5.6 Energy Policy Planning Approaches and Institutional Arrangements

This section reviews energy policy and planning approaches, which mainly focus on the energy supply, demand modelling exercises, and rural energy planning issues; and then summarises the existing institutional arrangements for the energy sector.

5.6.1 Energy Policies During the Eighth Plan Period

Energy development policy was not formally included in planning until the Sixth Five Year Plan (1975-1980). During this plan period, the hydropower and forestry sectors received priority. Alternative energy source development started to receive priority in the Seventh Plan period (1985-90). Three major energy policy objectives were envisaged in the Eighth Five Year Plan (1992097): 1) to increase consumption of electricity and support energy intensive industries with the development of hydropower; 2) to develop alternative and decentralised energy resources as a substitute for imported fuel; and 3) to ensure environmental protection. The plan adopted the following strategies to achieve these policy objectives (NPC 1992).

- Developing indigenous energy resources in the most efficient manner
- Cost effective and environmentally friendly energy conservation and demand management practices
- Financing for the execution of hydropower projects of different capacities
- Entering into energy import/export agreements if the net benefit is beneficial
- Pricing all energy to reflect social costs
- Addressing environmental problems associated with energy supply and demand in collaboration with both non-governmental and international agencies

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23 The covenants required to set a tariff in order to raise funds to cover cash operating expenses, debt servicing, and working capital, other than the cash and self-financing part of capital investment that comprises local investment and interest during construction. The earnings of NEA are also required to achieve a rate of return (ROR) on net operating fixed assets of 5 and 6% in FY 1995 and 1996, respectively (Shrestha 1996).

- Transferring the ownership of government owned energy sector utilities to the private sector in line with the privatisation policy

The plan set the targets of generating 292,700kW of additional electricity from power projects, constructing 30,000 units of biogas plants, and distributing 250,000 units of improved cooking stoves.

The Water and Energy Commission Secretariat (WECS) initiated development of a series of energy planning models as early as the 1980s (Box 5.7).

5.6.2 Rural Energy Planning Issues

At present, rural energy issues are not well integrated with rural development programmes. Rural energy issues are being addressed in a non-integrated fashion by individual line agencies. There is virtually no coordination between institutions on programme interventions, implementation, or monitoring (dLA and CRT 1997). There is no comprehensive rural energy planning as such in Nepal. Although a perspective energy plan has been formulated for the energy sector as a whole, as yet no long-term perspective plans for the rural energy sector have been developed. In the absence of such a plan it is difficult to make estimates for future allocation decisions in the rural energy programme. Rural energy planning should provide the basis for identifying the following critical functions that need to be performed or supported by the government: promotion, financial support, entrepreneurship development, regulation, monitoring and evaluation, equity, environmental protection, and research and development.

Rural energy planning calls for as much functional devolution as possible through participatory appraisal techniques (process learning approach) in planning, design, implementation, and monitoring and evaluation. The biogas, micro-hydro, and community forestry programmes and their success demonstrate that proper intervention can break through by capitalising on the local indigenous capacity for group organization, credit mobilisation, and development of entrepreneurship. However, many interventions have been less successful. The ADB/N acted for a long time as a rural energy planning and technology extension agency, most notably in micro-hydro and biogas projects, by combining credit operation with a support service. However, since the ADB/N was unable to generate a consistent and long-term commitment from either the government or from donor agencies, it is now moving towards a role of credit provision alone with limited technical assistance capabilities. The improved cooking stove programme undertaken by the Forest Department was primarily driven by centralized targets and limited to a single technology. There was no process learning, no monitoring and evaluation, and no decentralised strategy using local entrepreneurship or talent for group formation.

Box 5.7: WECS Energy Demand and Supply Modelling Exercise

The energy modelling framework developed by WECS is a series of computer models for analysing energy supply and demand. More important, these models analyse the sectoral end-use demand for the residential, agricultural, commercial, industrial, and transport sectors.

The Household sector Energy Model contains four sub-modelsdesegregated by physiographic and development region

- a district-wise population projection sub-model
- a fuelwood supply projection model based on Land Resource Mapping Project (LRMP) and other forest-related data
- an energy specific end use analysis model (household size and income elasticity as main explanatory variables), and
- a supply/demand balance and project/programme evaluation sub-model

The Transport sector Model contains desegregated information at two levels

- by mode of transport (road, ropeways, railways, aviation) and geographic region, and
- by end use and energy form

The Agricultural sector Energy Model contains desegregated information at three levels (activity, inputs and end uses for each major crop type)

The Industrial sector Model includes both traditional and modern industries (14 types of fuel and 24 subsectors)

The Commercial sector Energy Model includes schools, trading places, government, and non-government offices, and water supply by end uses and fuel types

The Energy Supply Projection Model

- fuelwood: forest depletion rates, area, and yield
- agricultural residues and animal wastes: crop and animal populations, and residue production factors

5.6.3 Institutional Arrangements in the Energy Sector

Institutional arrangements are necessary for pricing, resource mobilisation, energy development, environmental protection, energy resource management, energy technology and standards, and dissemination and outreach programmes. The institutions dealing with energy development in Nepal are predominantly under government ownership and are vertically integrated. The NEA, NOC (Nepal Oil Corporation), NCL, and TCN are examples of such organizations. However institutional responsibility for the energy sector is spread over many entities which include ministries, line ministries, and sector and sub-sector entities. There is no agency at the macro-level that deals solely with the development of a rural energy programme in an integrated fashion. Chart 5.1 lists the principal institutions involved in the energy sector (WECS 1994f).

There are many options possible for institutional arrangements at different stages in the energy delivery system or fuel chain. Centralized energy forms, such as coal or grid power, operating within a competitive market structure obviously present institutional needs and opportunities that are different decentralised options such as biogas or solar technologies in which energy is converted locally close to the point of use.

In the changing context of economic liberalisation, the challenges for the energy sector lie in liberalising and deregulating energy markets, providing more opportunities for private sector initiatives, and upgrading the efficiency of public utilities through accountable and autonomous management systems. Since the early 1990s, there have been several significant changes in the institutional framework for commercial energy supply activities in Nepal. Some of the strategies that have been adopted by the government in the context of economic liberalisation are as follow.

- Selective opening of the markets and greater reliance on market forces through competition, price deregulation, and simplification of market entry and exit
- Improvement in public sector efficiency through various administrative reform measures and changes in civil service staffing policy
- Improvements in the coordination among different institutions
- Steps towards modernisation of the market structure
- Tariff reforms and reduction of subsidies for power supplies and moves towards energy price deregulation
- Introduction of investment credit, profit repatriation facilities and other incentives for mobilisation of domestic and international funds
- Increased accountability and efficiency through restructuring of management in public sector institutions and an improved legal and regulatory framework

Chart 5.1: Institutions Dealing with Energy Development and Supply

Organization	Area of responsibility	Type of organiza -tion	Functions	Remarks
Ministry of Water Resources Nepal Electricity Authority Water and Energy Commission Small hydro development	Mainly water resources and hydropower development	HMG	Planning and project execution Surveys and study reports	No R& D facilities Deals with diesel, power plants, and solar, wind, and multi-fuel systems
Ministry of Industry Department of Mines and Zoology Project with UNDP assistance	Mineral resources (coal, lignite, natural gas, geothermal, petrol exploration) and efficiency of industrial boilers	HMG	Planning and project execution Surveys and study reports	
Ministry of Forest and Soil Conservation Department of Forest Projects with external assistance Remote sensing sector Forest resources survey	Forest resources and afforestation programmes	HMG	Planning and project execution Surveys and study reports	Biogas Promotion Project with assistance from SNV
Ministry of Local Development	Local development	HMG	Planning and project execution	
Ministry of Supply Nepal Coal Limited Nepal Oil Corporation Nepal Fuelwood Corporation	Supply of petroleum products, coal, and fuelwood	HMG	Planning and project execution Supply	
Ministry of Education and Culture RECAST, Tribhuvan Univer-sity Centre for Applied Research Institutes of Engineering Institutes of Science and Technology Institutes of Agriculture and Animal Science	R&D on alternative energy	HMG	Planning and project execution Surveys and study reports Teaching and R& D institutions	Centre for Research and Development (CARD) is a new centre established with Norwegian assistance
Ministry of Agriculture Department of Agriculture	Biogas , micro-hydropower	HMG	R & D activities	
National Planning Commission Alternative Energy Promotion Centre	Alternative energy	HMG	Planning, coordi-nation, and promotion of alternative energy	Newly proposed organization
Other government agencies RONAST, RECAST, Tribhuvan University	Alternative Energy		R& D on alternative energy	Ongoing project New & Renewable Energy Deve-lopment Centre (NRDC) for alternative energy with assistance from JICA (Japan's International Cooperation Agency)

5.7 Environmental Implications of Energy Use

Both the production, supply, and consumption of energy, especially fossil fuels and fuelwood, and different types of end-use technology can have an adverse effect on the environment. This section deals with the environmental implications of the use of different types of energy.

Hydropower

Hydropower development activities affect the environment (degradation, exhaustion of natural resources, and pollution), humans (displacement, cultural issues, and natural hazards/risks), and their institutions (sharing of benefits among diverse interest groups). Since most of the economically feasible power project sites in Nepal are located in sensitive natural areas, a great deal of environmental consideration is needed to minimise the adverse environmental effects.

Fossil Fuels

Burning of fossil fuels (petroleum products and coal) is starting to have a serious impact on the environment in urban areas as a result of the rise in vehicular traffic and the use of poor end-use technologies.[24]

The main impacts of fossil fuels during production and use are air pollution, the greenhouse effect, particulate pollution, and cooling effects. Fuel quality and end-use technologies are important for reducing unwanted emissions. The low quality coal used in industries (brick kilns) has a high sulphur content, and inhalation of the emitted gases is extremely harmful to health.

Biomass Energy

As a result of inadequate ventilation facilities and inefficient cooking stoves, the existing patterns of biomass energy use lead to various health problems, such as chronic bronchitis, and obstructive diseases such as asthma and emphysema. Indoor air pollution in Nepal is estimated to be five to 19 times greater than the accepted standard in developed countries. Improved cooking stoves reduce total suspended particals (TSP) by two-thirds (mg/m^3) and CO concentrations by three quarters in comparison with traditional stoves. The concentration of TSP in houses using traditional stoves can be as high as 380ppm, compared with 67ppm in houses using improved stoves[25] Nepal has high rates of infant and childhood mor-

[24] Combustion of fossil fuel gives rise to harmful gases such as sulphur dioxide, nitrogen oxide, carbon monoxide, and carbon dioxide

[25] The official health standard in the USA is 35ppm.

tality (WECS 1994g). Acute respiratory infection is one of the main causes of morbidity and mortality among children under five years of age.

Greenhouse Gases

Methane (CH_4) is the main greenhouse gas emitted in Nepal. It is mostly emitted from wet rice cultivation and cattle (56 % of the emissions), land-use changes (43%), and fossil fuels (1%). In terms of energy related emission, about 76 per cent of it is emitted from biomass, the rest from petroleum and coal. Carbon release per capita is the lowest (900kg) in Nepal compared to other developing countries. Emissions of SO_2, NO_x, and CO are likely to grow in urban areas because of poor standards and lack of enforcement.

5.7.1 Environmental Policy and Environmental Standards

Environmental issues only received priority from the time of the Seventh Plan (1985-1990). Since then environmental impact assessments (EIA) have become mandatory for all development projects. A national conservation strategy has been adopted and a National Environmental Protection Council (NEPC) created. The Nepal Bureau of Standards and Metrology (NBSM) is the only organization authorised to set environmental standards. But no formally approved quality standards exist. The NBSM is currently preparing national standards for drinking water and water quality standards for various industries, similar to the WHO standards (WECS 1994g).

Recently, standards for vehicular emissions for vehicles in Kathmandu Valley has been gazatted, which are as follow.

- The limit for emission of carbon monoxide from petrol engine vehicles (3%); and
- The smoke density level for diesel engines (not more than 65 Hartridge smoke units [H.S.U]).

There are basically three principal options for minimising greenhouse gases in the long term: a) improving efficiency in energy production and consumption; b) shifting the fuel mix; and c) reducing the rate of deforestation and increasing afforestation.

5.8 Major Findings and Suggestions

The major findings and implications that emerge from the present study are summarised briefly below.

5.8.1 Data Gaps and Issues in Energy Consumption and Supply

Existing data on energy consumption and supply are not all that satisfactory. The energy consumption data for the household sector seem to be more comprehensive than for other sectors (in terms of regional disaggregation), although even for the household sector there are certain gaps. The most important gaps in data are as follow. First, there are no records of the production of traditional energy resources (fuelwood, agricultural residues, and animal dung). As transactions in traditional forms of energy do not take place in the market, the prices attached to most of these energy sources cannot be considered realistic. Second, there is no breakdown of rural and urban energy consumption in sectors other than the household sector so that it is not possible to prepare separate overall energy balances for the rural and urban sectors. Third, there are no data on animate energy consumption by region in the agricultural sector, or on the number of vehicles in the operating fleet in the transport sector. Fourth, there are no data on energy consumption by end-use for each fuel type for most of the regional profiles. As such disaggregation has not been possible for other sectors in most of the regional profiles. Finally, end use efficiency information is very weak and the information required for improving it is lacking.

There is an urgent need to update the energy consumption, demand, and supply parameters through scientifically designed surveys, modelling, and regular monitoring. Energy Demand Analysis (EDA) involves forecasting energy demand and is needed for planning and managing of both energy demand and supply. It is an integral component of integrated energy planning and policy and involves compiling data consistently and systematically across different sectors and energy types, estimating shortages and excess demand, and quantifying the various factors that influence demand in different sectors. There is a difference between energy consumption and demand. While energy consumption gives a picture of how much energy of different types is consumed for any level of aggregation or disaggregation, depending on the data availability and need, energy demand estimation stipulates how different variables influence energy demand. In Nepal, estimation of energy demand has not been carried out adequately (see Banskota and Sharma [1994] for a study of energy demand in the manufacturing sector). Energy demand estimation is of considerable importance for planning and policy.

5.8.2 Energy Consumption and Supply Pattern

The outlook of the overall energy situation in Nepal is fairly bleak. For many years to come, biomass energy will dominate the overall energy scenario, and Nepal may face a critical challenge in raising energy supplies. The energy problem in Nepal stems largely from the fact that one form of energy (biomass fuel) is being consumed at an unsustainable rate, while another potential renewable resource (hydropower) remains virtually unused.

A central issue in the energy scene is the dominance of the household sector in total energy demand, and the importance of biomass fuel in this sector. About 91 per cent of the total final energy used in 1995 was consumed in the household sector and the remaining 10 per cent in industry (4.8%), transport (2.9%), commerce (1.4%), and agriculture (0.78%). About 91 per cent of the energy demand in 1995 was met from traditional sources, 7.2 per cent from petroleum fuels, and one per cent each from coal and electricity. Fuelwood is one of the principal forms of traditional energy accounting for over 80 per cent of the total final energy consumption in the country.

Estimates indicate that there is a gap between the demand and supply of biomass energy, implying that excess demand has to be met through overexploitation of forests. Overexploitation eventually leads to deforestation and consequently soil erosion, loss in agricultural productivity, flooding, and other problems. The intensity of this problem varies between different areas in the country. Developing sustainable biomass energy in a country like Nepal has the advantage of benefitting household energy demand in a relatively cheap manner, if the environmental benefits of increased biomass supply are taken into account. Improved management of biomass energy (both demand and supply) on a large scale must, therefore, be an integral part of overall energy planning in Nepal.

Consumption of commercial energy in the country is growing more rapidly than consumption of traditional energy, although the consumption level is still very low. The low level of commercial energy consumption (petroleum products, coal, and electricity) is a clear manifestation of the country's lack of industrialisation and low level of development. As the non-agricultural sector begins to contribute an increasing share to total GDP, the availability of a cheap and reliable energy supply will be very important.

In contrast to the urban areas where scope for inter-fuel substitution exists, the possibilities for substituting fuelwood by commercial fuel in rural areas are fairly limited. There are several reasons for this. First, fuelwood is normally collected during the slack season at no cost other than the labour time, the perceived value of which is low in many rural areas given the lack of alternative employment opportunities. Second, rural households use different types of energy in a complementary manner (for example biomass fuel for cooking and kerosene exclusively for lighting). This complementary energy use indicates a limited scope for inter-fuel substitution. Third, rampant poverty, population growth, and a low level of education will remain as major impediments to switching rural households from fuelwood to higher cost commercial fuels. Even if the cost of wood increases as a result of scarcity, it is unlikely that it will be substituted by modern fuels given the possibilities for using other biomass fuels such as crop residues and animal dung. This is corroborated by the findings of the present study that the transition from fuelwood to other sources of biomass fuel (agricultural residues and animal dung) is more pronounced in rural *Terai* areas, whereas a transition from fuelwood to commercial fuel is observed in urban areas, especially in the urban hills.

Even though there appears to be abundant potential for hydropower, actual generation has remained a dream with less than 260MW generated at present. The slow pace of transition from traditional to commercial fuels, particularly the lack of exploitation of the vast hydropower potential, indicates that planning and policies in this sector have been inadequate to provide incentives for investment. Lately, policy reforms have taken place with the intention of attracting the private sector. However, given the overall poverty in Nepal, the private sector will not be able to undertake large-scale projects, and the policies should be designed to attract foreign investments. India has a huge energy deficit so there will always be a market for electricity, and planning needs to be done accordingly.

In a country like Nepal, the importance of energy demand and supply management may be seen from three different viewpoints. In the first place, biomass energy (fuelwood, animal dung, agricultural residues, fodder) constitutes the major source of energy for meeting household energy needs. Second, despite commercial energy accounting for less than 10 per cent of the total energy demand, it takes a heavy toll on the nation's limited foreign exchange earnings. As a result of poor macroeconomic policies (trade deficit and depreciating exchange rate), there is an annual increase in real growth in the foreign exchange reserves used for commercial energy. Third, potential energy reserves remain largely unexploited despite being large. Hence, energy demand continues to grow as the population grows, but the supply from domestic sources remains largely undeveloped and poorly managed.

5.8.3 Renewable Energy Technologies

The development of other RETs in Nepal is still in the fledgling stage and generally expensive and beyond the reach of the common people. Sociocultural and economic barriers have hampered the adoption of RETs on a large-scale. In the past the implementation of renewable energy projects has not been very effective or encouraging. The issues that have emerged related to the development and promotion of RETs can be broadly grouped into:

- social issues (non-acceptance of the technology);
- planning and policy issues (lack of willingness at the policy level);
- institutional issues (non-existence of responsible coordinating bodies);

- financial issues (high initial investment);
- technical issues (weak infrastructure); and
- managerial issues (lack of marketing skills).

The most striking issue has been the gap in coordination and inter-organizational communication between agencies dealing with the planning and implementation of renewable energy projects. As a result of the lack of such coordination, most of the problems remain unattended and have adversely affected the production and promotion of renewable energy technology devices. This has also affected the introduction of other renewable energy technologies that have scope for promotion.

5.8.4 Energy Efficiency Issues and Options

The prevailing patterns of biomass energy use are characterised by extensive production with inefficient and irrational supply management, diversion of crops and livestock residues from soil fertilization, and highly inefficient combustion of biomass fuels. As a result the country's gross biomass energy consumption actually reflects a low utilisation of useful energy (energy efficiency only 14%). The greatest inefficiency in the energy system occurs in the end use. In general end-use energy efficiencies are low by world standards. Thus the resource costs of many activities in Nepal are non-competitive at a higher level. Technical inefficiency in energy end use occurs in the household, commercial, and institutional sectors.

The transport sector, which is primarily a private sector activity, operates more efficiently than other energy consuming sectors. Nevertheless, some of the inefficiencies prevailing in this sector include excess trucking capacity and hence underutilisation of trucking capital, relatively high transport costs as a result of the lack of larger vehicles, and a low level of expenditure on road maintenance.

In the household sector, biomass stoves are both inefficient and a serious hazard to health. Dung and agricultural residues are the least efficient and most polluting. Even kerosene stoves operate at low efficiency. In the commercial sector both biomass cooking stoves (in institutions) and kerosene stoves (in tea shops) operate at low efficiency. Most of the electrical energy supplied for space heating and cooling and illumination is wasted as a result of high peak power demand and useless use of electricity. In the industrial sector, electrical use and reactive power loss are high because of inefficient lighting systems and motor pump compressors.

5.8.5 Options for Improving Energy Efficiency

Poverty, population growth, and low levels of education are the main impediments to improving energy efficiency in many developing countries, including Nepal. This implies that energy efficiency policies should be directed to these serious problems.

Pricing is extremely important for the efficient use of energy. Energy price distortion and related problems are an obstacle to efficient pricing. The market structure of energy in Nepal is dominated by the para state entities, especially in the oil and electricity sectors. It is essential to commercialise the energy supply companies, to increase productivity, to provide incentives for continued productivity, to allow more independent governance, and to achieve full cost recovery.

While market forces are deemed important for promoting economic efficiency, the presence of a significant amount of unpriced energy (i.e.; biomass fuels) reduces the impact of these. Use of this unpriced energy can have a significant environmental impact and environmental cost. But there is no direct way of including such effects in price estimates. The problem is particularly apparent in Nepal, which does not have any institutional mechanism to address such factors or internalise environmental costs.

There is an urgent need to develop and enforce efficiency standards based on agreements with manufacturers and producers. Incentives to consumers to conserve energy (such as preparing a demand side management programme) should be combined with incentives to producers to perform R&D and produce market technologies.

Both increases in the price of energy and changes in technology can lead to improvements in energy use. Promoting the adoption of more efficient energy technologies requires a variety of policies to encourage end users and producers to improve efficiency while reducing environmental problems. First, it is essential to abolish subsidies for energy production and consumption. The rationale for subsidising any energy price is to provide benefits to the poor, but as long as the poor have a limited choice of energy, price subsidies are not likely to achieve the desired result. It is difficult to target the poor exclusively, and there are more important uses of government funds than energy to help the poor. Second, supporting private/ public partnerships and R&D is equally important for fostering the dissemination of energy efficient technologies. Third, transport and industrial policies are needed that promote the development of efficient technologies. Finally, there is a need to internalise environmental costs through taxes and fees.

5.8.6 Policy Planning and Institutional Issues

Rural energy issues in Nepal are not well integrated into rural development programmes. The lack of complementary investment action limits the prospects for successful implementation of the rural energy plan and programme. Nor is there any agency at the micro- or macro-level that deals solely with the development of the rural energy programme in an integrated fashion.

Although WECS is performing assessments of rural energy consumption by fuel and end-use types, there is no direct coordination in energy planning and implementation between institutions. Institutional responsibility for the energy sector is spread over many entities which include ministries, line ministries, and sector and subsector entities. Thus rural energy issues are being addressed in a non-integrated fashion by these individual agencies. There is virtually no coordination between institutions on programme interventions, implementation, or monitoring. There is no comprehensive rural energy planning as such in Nepal. Although a perspective energy plan has been formulated for the energy sector as a whole, as yet no long-term plans have been developed for the rural energy sector. In the absence of such a plan it is difficult to make estimates for future allocation decisions in the rural energy programme.

Rural energy planning calls for as much functional devolution as possible through participatory appraisal techniques (process learning approach) in planning, design, implementation, and monitoring and evaluation. The biogas, micro-hydro, and community forestry programmes, and their success, demonstrate that proper intervention can break through by capitalising on the local indigenous capacity for group organization, credit mobilisation, and development of entrepreneurship. However, many interventions have been less successful. The improved cooking stove programme undertaken by the forest department was driven primarily by centralized targets and limited to a single technology. There was no process learning, no monitoring and evaluation, and no decentralised strategy using local entrepreneurship or talent for group formation. As such the national programme was bound to receive'a setback when donor assistance was reduced.

Finally, HMG's recent policy of decentralization will have an important influence on rural development and hence rural energy planning. There has been significant development in this policy recently with the implementation of various programmes at the village development committee level.

5.8.7 Reforms Needed in the Energy Sector

The role of the government in the changed situation must focus on formulating indicative planning, regulating natural monopolies, and creating an environment for competitiveness. Markets that can be made competitive should be deregulated. These include the fields of generation and distribution of electricity, importation and distribution of petroleum products, and marketing of fuelwood and other tradeable commodities. The private sector can participate in a variety of ways in the energy sector, especially in production and distribution, and can help the government to free resources needed in other sectors. Monopoly in the ownership of energy industries and management must be reduced wherever possible. There are, however, certain natural monopolies or legally protected monopolies where regulation should act as a market substitute and management efficiency should be fostered by the government.

5.8.8 Finance and Investment Issues

The process of energy transformation is capital intensive. Nepal 's ability to harness its energy resources is contingent on the flow of capital investment. Slower economic growth means that there will be significant decline in energy investment in relation to GDP. The combination of subsidised prices and poor economic performance has made it difficult to attract private savings, leaving the public sector with the responsibility for raising the necessary resources.

In Nepal, the challenge of financing rural energy programmes is exacerbated by the characteristics of local investors - individual households or groups with limited assets and skills. The suppliers of technology also restrict investment transactions. These players in the rural energy market are often small, have limited financial markets, and are often limited in their experience and expertise. At the same time, the scale of intervention is too small to support the market presence of many commercial suppliers.

There is a need for the accessible presence in the market of suppliers of both equipment technology and know-how (technical intermediation). If there is a group involved in rural energy supply, there will also be a need for social organizational intermediation to assist in the creation and strengthening of the institution. This is especially important for ensuring the sustainability of the rural energy system in Nepal because of the evolving roles of user groups, VDCs, and local NGOs.

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Renewable Energy Technology Exhibition at the ICIMOD (PARDYP) project site, Dolakha, Nepal

Nepali woman preparing *Dhindo* in an improved cooking stove

Turbine of a multipurpose power unit (MPPU), Nepal - *CRT*

Chapter 6

Pattern of Energy Use in the HKH Region of Pakistan

by
M. Abdullah and K. Rijal

6.1 Introduction

6.1.1 Country Background

Pakistan has an area of 796,095 sq.km. and an estimated population of 128 million (in1995) (Sharma et al. 1997). The population growth rate remains rapid at around three per cent per annum. The country contains different physical regions, a) the western off-shoot of the Himalayas which cover its northwestern parts, b) the Balochistan Plateau, c) the Potohar Plateau and Salt Range, and d) the Indus Plain, the most fertile and densely populated area. The River Indus, which originates in Tibet, flows through the Karakoram range, Gilgit, Swat, and Attock, and from there it enters the plains of Punjab, proceeds through Sindh, and finally enters into the Arabian Sea. About 61.5 per cent of the country is mountainous with the Himalayas and Karakoram Mountains in the north and the Sulaiman and Brauhi ranges in the west.

The climate varies from region to region. The north and western mountain ranges are extremely cold during winter, while the summer months - April to September - are pleasant. The plains of the Indus Valley are very warm in the summer and cold and dry in winter. In the south the climate is temperate most of the year. Pakistan has an agricultural economy with a large network of irrigation canals. Wheat, rice, cotton, millet, and sugarcane are the main crops. The principal fruits are oranges, mangoes, bananas, and peaches. The main mineral resources are natural gas, coal, salt, iron ore, marble, copper, and chrome ore. The per capita income is about US $ 350 per year (GOP 1996). About 4.8 per cent of the total land area is covered by forest, with 1.12 million hectares of production forests and 3.15 million hectares of protection forest (FSMP 1992).

Administratively, Pakistan is divided into four provinces: Punjab, North West Frontier, Sind, and Balochistan. The Provinces enjoy a large degree of autonomy. The Northern Areas and the Federally Administered Tribal Areas (FATA) are administered by the Federal Government.

6.1.2 The Energy Situation in Pakistan

The total final energy consumption in the FY 1994/5 was 1,929 million GJ. Fifty per cent of the total energy is obtained from biomass fuels, out of which fuelwood supplies 59 per cent, agricultural residues 22 per cent, and animal dung 19 per cent. The main commercial sources of energy in Pakistan are natural gas, oil, coal, and hydropower. Pakistan imports petroleum, LPG, and coal to meet its energy needs. The import dependency, the ratio between imports and net supply, increased from 28 per cent in 1991 to 42 per cent in 1995.

The proven and estimated reserves, energy supply, and consumption of different fuel types are shown in Table 6.1. Oil and gas comprise 59 per cent of the proven reserves of commercial fuel, but only 14 per cent of the estimated reserves. Coal comprises 39 per cent of the proven reserves of commercial fuel but 86 per cent of the estimated reserves. The estimated hydroelectricity potential is 30,000MW. The number of electricity consumers has been increasing at a rapid rate as a result of urbanisation and village electrification. There was an average annual growth of 10.6 per cent in the number of consumers between 1960 and 1994. The generation capacity is insufficient to meet the demand all year round. At times of low river flows, load shedding (scheduled power cuts) has to be resorted to during peak load hours.

Oil and gas remained the largest energy components, together contributing nearly 77 per cent of the total commercial supplies. Indigenous oil production supplied about 42 per cent of the total oil consumed, and the rest had to be imported at a cost of nearly 1.2 billion dollars. Natural gas contributed significantly, supplying 35 per cent of the total energy from commercial fuels. In order to enhance the availability of natural gas in the country, a Memorandum of Understanding (MOU) worth $7 billion has been signed with Qatar and Iran for import of gas (GOP 1996). An MOU has also been signed for importing gas from Turkmenistan.

Table 6.1: Energy Supply and Consumption, FY 1994/95

Sources	Units	Estimated Reserves	Proven Reserves	Energy Supply	Final Consumption
Oil	Million GJ	2448	949	646	462
Gas	Million GJ	42451	20681	579	283
Coal	Million GJ	272695	14328	90	76
Electricity	Million GJ			193	142
-Hydro			500	83	61
-Thermal				110	81
Biomass	Million GJ				967
-Fuelwood				379	574
-Agricultural Residue					209
-AnimalDung					184
Total	Million GJ	317594	36458	1398	1929

Sources: Hamadani 1996; HESS Report 1993; Pakistan Energy Year Book 1995

The two sectors that consume the most commercial energy are the industrial and transport sectors, which consume 38 per cent and 31 per cent of total commercial energy respectively. The household sector occupies the third position with a share of 19 per cent. The transport sector is heavily dependent upon high speed diesel (78%) and motor spirit (16%). In the industrial sector, 46 per cent of the energy consumed is provided by gas, followed by oil with a share of 22 per cent, coal with 20 per cent and electricity with 12 per cent. Gas supplied about 55 per cent of the total commercial energy used in the household sector and electricity 29 per cent. The two main sources of commercial energy used in the agricultural sector are electricity (65%) and oil (35%).

6.1.3 The Hindu Kush-Himalayan Region of Pakistan

The mountain area of Pakistan covers the greater part of Balochistan (the western mountains) and the North West Frontier Province (NWFP), the Northern Areas, the Federally Administered Tribal Areas (FATA), and Azad Jammu & Kashmir (AJK) (the northern mountains). The Northern Areas, FATA, and AJK are completely mountainous, and 20 of the 26 districts of Balochistan and 16 of the 21 districts of the NWFP are mainly mountainous. The mountain areas together account for about 477,000 sq.km., or 60 per cent of the total land area of the country. In 1981, when the last census was conducted, these areas had 17.4 per cent of the total population of Pakistan at that time. The estimated population in 1995 was about 24.2 million, or 18.2 per cent of the total estimated 1995 population. The population growth rates in the mountain areas vary; the rates being higher in the mountains of the NWFP, Balochistan, and the Northern Areas (in excess of 3.5 per cent), and lower in AJK. FATA experienced negative growth between 1972 and 1981. There is no information on the growth rates from 1981 to the present day.

The two main mountain regions of Pakistan — the western dry mountains and the northern mountains (Sharma et al. 1997) — display very distinct geoclimatic conditions, resources, demographic characteristics, and population resource relationships, which have implications for sustainability.

The Western Mountains of Balochistan

Balochistan is the largest of the provinces of Pakistan and contains over 43 per cent of Pakistan's land area. Its terrain becomes increasingly mountainous from the south-south-west to the north. The highlands comprise three distinct geographical regions: the Himalayan mountains and adjacent regions to the north, the Sulaiman range and its extensions in the centre, and the Balochistan plateau proper to the west. The latter is the eastern extension of the Iranian plateau. The valleys in the highlands generally lie at heights of between 1,000 and 2,000m, the highest peak, Loe Sar, lies at 3,520m (Sharma et al. 1997). High and low mountains, gravelly fans and terraces, and the Piedmont Plain together comprise roughly 85 per cent of the total area of Balochistan. Temperatures can vary considerably, the winter temperature in the high valleys may fall as low as -20°C while in summer the temperatures may soar as high as 40°C. Summers in general are mostly dry. Rain mostly falls in the winter. Rainfall varies from about 50mm in the south to about 400mm in the north. Aridity is the most pronounced climatic characteristic of Balochistan. Only about 1.7 million ha (4.9 per cent of the total land area) is cultivated at all, and only about two per cent of the total land area is cultivated at any one time, mainly as a result of the scarcity of water. Forests cover 3.1 per cent of the area. However 70 to 80 per cent of the state forests are grass and shrubs (BOS 1996). Rangelands are the most extensive land-use category in Balochistan, covering some 30 million ha of the total geographical area of 34.7 million ha.

Balochistan as a whole had a population of 4.3 million in 1981 with an annual growth rate of seven per cent between 1972 and 1981. The estimated population in 1995 is 7.4 million with an average annual growth rate of 3.8 per cent. The gross density is only 21/km² and the density in rural areas is around 12/km². The population is largely illiterate. About eight per cent of the population lives in poverty (Sharma et al. 1997).

Agriculture, including animal husbandry, is the main activity and, in 1981, involved 69 per cent of the labour force. Crop production and horticulture, however, are heavily dependent on irrigation, which in turn requires considerable extraction of the groundwater resources. In recent decades production of horticultural crops has increased significantly, expansion of orchards is estimated at seven per cent annually. Balochistan produces over 80 per cent of the total production of almonds, apples, apricots, grapes, and pomegranates in Pakistan.

The province has considerable mineral wealth. It produces natural gas, coal, chromite, lead, sulphur, and marble. Natural gas was discovered at Sui in Kachhi district in 1952. There are estimated to be four trillion cu.ft. of recoverable resources of natural gas in the province. Gas is piped from Sui to all major cities in Pakistan. There are coal reserves at a number of places in the province, with a total of 53 million tonnes of measured reserves. Chromite is mined at Hindubagh, mostly for export. Good quality marble is found at Dalbandi and Chagai. Sulphur is found at Koh Sultanin Chagai.

The Northern Mountains

Broadly, the northern mountains comprise the area covering principal parts of the North West Frontier Province, FATA, the Northern Areas, and AJK. Thus they include parts of the Himalayas, the Karakoram, and the eastern extension of the Hindu Kush mountain ranges. The high Himalayas act as a barrier to the rain-bearing monsoon winds. The mountain ranges comprise a chain of high mountain peaks crowned by the Nanga Parbat at 8,126m. The relatively low elevation mountains of Azad Kashmir, Hazara, Swat, Kohistan, and Dir also belong to this chain. The Karakoram and Hindu Kush ranges are called the trans-Himalayan ranges. The region contains some of the world's largest glaciers (Sharma et al. 1997). The northern mountains have a wide diversity of climatic features. The climate in the valleys of the Karakoram is dry with harsh winters and meagre life support systems. Precipitation is mainly in the form of snow. The precipitation decreases to the north to about 125mm annually. The southern aspects of the lower Himalayas receive some of the heaviest precipitation. All the principal rivers of Pakistan originate or pass through the northern mountains. They constitute the main source of water for irrigation as well as for hydropower generation.

The total population of the NWFP, FATA, the Northern Areas, and AJK in 1981 was about 12 million (excluding the approximately 2.5 million refugees from Afghanistan). The 1994/95 estimates indicate a population of about 18.7 million, but these figures do not include those desplaced by conflicts in neighbouring Afghanistan growing at a rate of about 3.3 per cent per annum. The population density was about 69/km^2 in 1981, and about 107/km^2 in 1994/95. The Northern Areas are relatively sparsely populated, with a density of only 12/km^2. A notable feature of population in these mountains is the high interprovincial migration. There is a relatively low urban growth rate indicating a low rate of rural to urban migration (Sharma et al. 1997).

The NWFP, FATA, Northern Areas, and AJK together have an area of about 174,000 sq.km. The mountain areas contain 60 per cent of the forest in Pakistan. In 1993, 17 per cent of the area of NWFP is estimated to be under forests. Within the NWFP was percentage of area covered by forest is higher in relatively wet mountain districts such as Abottabad (32.6%), Manshera (65.8%), and Battgram (41.8%). In recent years there appears to have been some increase in agricultural area, while the area under forests may have declined slightly. In contrast, only four per cent of the Northern Areas is covered by forest. The proportion of cultivated land is also miniscule (less than 1%) as is the proportion of cultivable waste (also less than 1%), largely as a result of the rough terrain, low rainfall, and the problem of irrigation. The area under forest in AJK is relatively high (41%), as is the cultivated area (13%). The vegetation cover in this area is much better, largely as a result of the higher rainfall.

The 1981 census showed a literacy rate of 17 per cent for the NWFP with a female literacy of only 6.5 per cent. Mountain districts such as Battgram, Kohistan, and Shangla Par had total literacy rates below five per cent. The 1991/92 estimates give urban literacy at 36 per cent and rural literacy at about 13 per cent. There has been no significant change in female literacy since then. The NWFP and the Northern Areas have some of the highest levels of poverty in Pakistan. In 1991 the average poverty level in the rural areas of the NWFP was reported to be 21.4 per cent.

There is little manufacturing. The important industries within the NWFP province are sugar refining, fruit canning and preservation, and tobacco curing. Other industries include cement, edible oil, textiles, and grain milling. The province is rich in mineral resources. Coal, limestone, and marble are mined and emeralds are found in Swat. There is a great potential for producing hydroelectricity within the province. Tarbela, Warsak, Malakand, and Dargai are the main hydroelectricity stations at present. They produce nearly 3,760MW of electricity. The province has a small reserve of coal at Hangu, which is estimated at 81 million tonnes. There are no reserves of oil or gas in the province.

6.2 Energy Resource Base and Supply Situation

Commercial Energy

At present only 25 per cent of petroleum consumed in the country is produced in Pakistan, the remainder is met through imports costing 1.2 billion US dollars per annum. Almost 12 per cent of the total petroleum fuel is consumed in the mountain areas, which possess only 1.5 per cent of recoverable reserves. The ratio of recoverable reserves to production of oil indicates that the reserves will last for only 10 years. However, there is a big gap between the proven reserves and the estimated total potential resources (Table 6.2). The gas supply in Pakistan is mainly domestic. There is about 0.85 trillion m^3 of proven gas reserves, of which one-third is in the mountain areas (primarily in the western mountains in Balochistan). The ratio of recoverable reserves to production of natural gas indicates that the reserves will last for 33 years in Pakistan and 12 years in Balochistan.

Table 6.2: Potential Resources and Proven Reserves of Conventional Commercial Energy Forms in Pakistan

Energy Forms	Potential Resources	Proven So far	Balance Recoverable Reserves	Production FY 94/95	Ratio of Reserves to Production
Oil (million barrels)	40,000	515	198	19.9	10
Gas (trillion cu. m.)	5.67	0.85	0.595	0.017	33
Coal (million tonnes)	184,655	1,686		3.0	554
Hydropower (MW)	30,000	4,726		4,726	
Mountain Areas					
Oil (million barrels)		3.1	2.9	0	
Gas (trillion cu. m.)		0.303	0.116	0.0085	12
Coal (million tonnes)		54		1.7	32
Hydropower (MW)	30,000	4,726		4,726	

Sources: Raza (1995); HESS (1993); FSMP (1992); Pakistan Energy Year Book (1995)

There are 1,686 million tonnes of proven reserves of coal in Pakistan, of which a little more than three per cent is in mountain areas. The ratio of recoverable reserves to production of coal is more than 500 for the whole of Pakistan, but only 32 in the mountains. Though the potential resources of coal (184 billion tonnes) are vast, the quality of these reserves is low (ranked as sub-bituminous to lignitic). The biggest deposit (175 billion tonnes) is located in the Thar desert and is a low-grade lignite.

Biomass

Biomass fuels - wood, shrubs, dung, and agricultural residues - are the main cooking and heating fuels used domestically by 87 per cent of the rural and 65 per cent of the urban households in Pakistan. In the mountain areas, 98 per cent of rural and 75 per cent of urban households depend on biomass fuels (HESS 1993).

Forest Resources

Public forest areas in the mountains (76% of total forest area in Pakistan), including coniferous forests (58%), scrub (33%), riverine forests (1%), farmland trees (4%), and irrigated and linear plantation (4%), provide most of the wood required for household and industrial purposes within both the mountains and plains of Pakistan (Table 6.3). About 14 per cent of the northern mountain area is covered by forest, although there is a significant variation in forest cover, from 15 to 60 per cent at district level. The northern and western mountains contain 82 and 18 per cent respectively of the total forest area in the mountains. Coniferous forests (70%) and scrub (21%) dominate in the northern mountains and scrub forest (85%) in the western mountains.

Table 6.3: FSMP Estimates of Forest Area in Thousand Hectares

Description	Western Mountains	Northern Mountains	Total Mountains	Pakistan Total	% in Mountains
Coniferous Forest	42	1,841	1,883	1,913	98
Scrub Forest	504	555	1,059	1,775	60
Riverine Forest	20	14	34	173	20
Mangrove Forest	2	0	2	207	1
Farmland Trees	23	83	106	466	23
Linear Plantation (Irri/Misc)	1	132	133	274	49
Total Forest	592	2,625	3,217	4,224	76
Geographical Area	34,719	18,544	53,263	87,980	61
% Forest Cover	1.7%	14.2%	6%	4.8%	

Irri = irrigation; Misc = Miscellaneous
Source: FSMP, Vol. 1 (1992)

Wood is harvested under prescribed yields from regulated areas. These areas cover the following proportions of forests in mountain areas under the control of the Forest Department i) NWFP (53%); ii) Balochistan (none); Northern Areas (9%); and AJK (100%). The recorded annual output of fuelwood in these areas is: I) NWFP (14,000 cu.m.); ii) Balochistan (1,000 cu.m.) Northern Areas (1,000 cu.m.); and AJK (none). It is clear, however, that a lot more than the recorded output is being removed from public forests, but no records exist of how much is actually being taken (FSMP 1992; Sheikh and Jan 1992). For example, the recorded annual output of fuelwood in the NWFP mountain area is 14,000 cu.m., whereas the estimated consumption in the household and industrial sector is about five million cu.m.. Fuelwood is either collected free of cost or purchased from the market. The fuelwood market is entirely in the hands of private traders, and there is very little scope for the government to regulate the price of fuelwood.

The estimated potential annual sustainable yield of wood from present forests is shown in Table 6.4. Coniferous forests contribute almost 51 per cent of the estimated potential supply in the mountains, farmland trees 25 per cent, and scrub forest nine per cent. Farmland trees and scrub forest contribute 72 and 19 per cent respectively of the total sustainable yield of forest in the western mountains; whereas in the northern mountains coniferous forest contributes 55 per cent, farmland trees 21 per cent, and scrub forest eight per cent.

Table 6.4: FSMP Estimates of Forest Growth in Thousand cu.m. Per Annum

Description	Western Mountains	Northern Mountains	Total Mountains	% of total in Mountains	Pakistan total
Coniferous Forest	8	3,229	3,237	99	3,282
Scrub Forest	101	444	545	91	598
Riverine Forest	40	37	77	11	692
Mangrove Forest	0	0	0	0	29
Farmland Trees	391	1,194	1,585	16	9,703
Linear Plantation (Irri/Misc)	4	0	4	>0.2	2,172
Total Growth	545	5,822	6,367	39	16,475

Irri = irrigation; Misc = Miscelleaneous
Source: FSMP, Vol. 1 (1992)

Other Biomass Resources

Other biomass resources (agricultural residues and animal dung) are being used increasingly in the mountain areas as a result of the increasing deficit in wood. There are no proper estimates of the potential supply of these residues, but various studies (HESS 1993; Rijal 1996a; Ramani et al. 1995) have indicated that they have competing uses as fuel, fodder, and fertilizer. The tendency of diverting these residues into fire to meet cooking and heating needs instead of using them as fodder and fertilizer is one of the critical concerns in the mountain areas of Pakistan.

Commercial Energy

The commercial energy requirements in the mountain areas of Pakistan are currently met by imported and domestic oil, natural gas, imported and domestic coal, and hydroelectricity power. In general, the potential supply of indigenous fossil fuels in the mountains is not significant and cannot meet the increasing energy demand in the area.

There is no oil production in the mountain areas and there is a uniform fixed price for oil products. However, there may be problems of availability in distant mountain areas, and studies have reported lower prices and substantial subregional price differences for diesel and kerosene in the western mountains as a result of smuggling of these products from Iran.

The main gas fields in the mountain areas are located in the western mountains in Sui, Pirkoh, and Loti. The annual production of gas from these fields has remained nearly constant at 325,000 to 350,000 million cu.ft. annually during the last five years (Pakistan Energy Year Book 1995). There are 4.1 trillion cu. ft proven recoverable reserves of gas in Balochistan. At present there is an installed capacity of 100MW of thermal power generation from gas and 5,293km of gas distribution pipeline in mountain areas (60% in the northern and 40% in the western mountains). The pipeline represents less than 13 per cent of the total gas distribution network in Pakistan, reflecting the difficulty and price of laying gas pipelines in this area.

Coal production in the mountains in the FY 1994/95 amounted to 1.6 million tonnes, of which 97.4 per cent was produced in Balochistan. There are 54 million tonnes total estimated reserves of coal in mountain areas (Paracha 1987; DMP 1996). Two small turbines with a capacity of 7.5MW each were installed in 1964 at Quetta to utilise Balochistan coal.

The northern mountains are rich in hydropower resources. According to some estimates, these areas have a potential of 30,000MW. In the FY 1994/95, the total installed capacity from hydropower was 4,726MW (40% of the total installed capacity for electricity generation in Pakistan) generating 22,858GWh. In the same year mountain areas consumed 8,245GWh, making them net exporters of electricity. There are 3,042km of transmission line in the NWFP and 2,456km. in Balochistan, together representing 20 per cent of the total length of transmission line in Pakistan. Illegal connections, theft, and high defaulters (those not paying electricity bills) are common features. This results in transmission and distribution losses in excess of 25 per cent. The system load factor is 62 per cent because of frequent load-shedding.

The Master Plan for the development of small hydropower identified 221 sites for small hydroelectricity schemes, out of which 116 sites were considered feasible. The total potential of the feasible sites is about 400MW. During the course of studies and field investigations for these schemes, a huge potential was observed for medium and major hydroelectricity schemes on the tributaries of the River Indus. The total identified potential of medium hydroelectricity schemes is 770MW, ranging from 10MW to 150MW (SHYDO n.d).

New and Renewable Energy Systems

The mountain areas of Pakistan have an enormous potential for mini- and micro-hydropower (MMHP), totalling about 500MW. MMHP plants have been quite successful in the mountains, and there are about 245 plants in operation installed by various government and non-government organizations (SHYDO n.d). At some plants local communities have set up cottage industrial units which operate during the day transmitting power directly from the shaft of the plants.

There is a great potential for using solar energy. Ten solar photovoltaic power stations with a total of 193.54kW installed in the NWFP and Balochistan, however, are out of order, and have not been in working condition for a long time. And no serious effort has been made as yet by any agency to work on solar cooking or solar water heating devices (Pakistan Energy Year Book 1995).

There appear to be two promising areas for geothermal power. These are the Chagai Volcanic Arc in the western mountains and the Himalayan Thrust Zone in the northern mountains. The amount of power that might be feasible is about 1,000MW, but serious effort is required to assess the potential fully (Raza et al. 1995; Bender and Raza 1995).

A variety of designs for improved cooking stoves proven efficient under laboratory conditions have been found to be unsuitable in the field. So far, about 65,000 fuel efficient cooking stoves have been distributed to various parts of the NWFP by the PCAT. The fuel efficient cooking stoves have been only moderately accepted by the rural populace, and a lot of effort will be needed for wider distribution.

About 4,165 biogas plants have been installed in Pakistan in the past, 1,343 of them in the NWFP, Balochistan, and AJK (Pakistan Energy Year Book 1995). Most of these plants were of the floating drum type (popularly known as the Indian design). Very few of the plants are in operation, however, and the biogas programme can be said to have failed miserably in Pakistan.

6.3 The Energy Consumption Pattern in Mountain Areas

There is reliable information over time on energy supply and consumption of commercial fuels. Preliminary estimates for the supply and demand of traditional fuels have also been made in the Household Energy sector Strategy and Forestry Sector Master Plan. These recent studies show that the total final energy consumption in Pakistan is about 1,929 million GJ per annum, 50 per cent in the form of commercial energy and 50 per cent as biomass fuels. The mountain areas of Pakistan account for 345 million GJ, about 18 per cent of the total final energy consumed in Pakistan, 33 per cent in the form of commercial energy and 67 per cent biomass fuels.

6.3.1 Final Energy Consumption Pattern by Sector and Fuel Type

The final energy consumption pattern by sector and fuel type in the mountain areas of Pakistan and in the country as a whole is shown in Table 6.5. The main findings are a) mountain areas are much more dependent on biomass fuels (67% compared to 24%); b) in the mountains the household sector consumes more than 70 per cent of total final energy (compared with 24% in Pakistan overall); c) the per capita final energy consumption in the mountains is lower than in Pakistan overall (12 GJ versus 15 GJ); and d) the per capita useful energy consumed in the mountain areas is almost half that in other parts of the country since the principal fuel used in mountain area is biomass which is used more inefficiently than fossil fuels. These patterns indicate both the low level of the energy supply infrastructure in the mountains and the lack of purchasing power of the mountain population.

Table 6.5: Final Energy Consumption Pattern, FY 1994/95

Description	Mountain Areas		Per cent of Pakistan	Pakistan	
	'000 GJ	Per cent		'000 GJ	Per cent
By Sector					
Households	245,887	71	24	1,043,992	54
Commercial/Institutional	7,491	2	7	111,595	6
Industrial	46,493	14	11	438,127	23
Agriculture	6,719	2	19	34,561	2
Transport	38,741	11	13	300,944	16
Total	345,331	100	18	1,929,218	100
By Fuel Type					
Biomass Fuels	232,834	67	24	967,042	50
Coal	6,135	2	8	75,735	4
Petroleum Fuels	56,381	16	12	461,584	24
Natural Gas	20,431	6	7	282,844	15
Electricity	29,684	9	21	142,013	7
Total	345,331	100	18	1,929,218	100

Sources: Study estimates based on HESS (1993); FSMP (1992); Pakistan Energy Year Book (1995).

The majority of households in HKH areas are rural (82% in the NWFP, 58% in Balochistan). Thus rural communities control, to a great extent, the overall energy consumption pattern in the area. It is also clear from the data that fuelwood is used by the majority of households in both urban and rural areas (for example 70% in urban and 97% in rural areas of NWFP).

Table 6.6 shows the per capita consumption of final energy by sector and fuel type in the northern and western mountain areas separately. Energy consumption per capita is almost 1.4 times higher in the western mountains than in the northern mountains. Other striking differences are: a) the household sector in the western mountains consumes about 80 per cent of total final energy and that in the northern mountains less than 70 per cent; b) the percentage of final energy consumed in the industrial and transport sectors in the northern mountains is higher than in the western mountains; and c) both the per capita consumption of and the percentage of total final energy provided by commercial fuels is higher in the northern mountains than in the western mountains. The pattern of energy consumption reflects both the inadequacy of the commercial energy supply infrastructure in the western mountains and the low level of industrial development and poor transport infrastructure.

Table 6.6: Per Capita Final Energy Consumption Pattern in the Mountains of Pakistan, FY 1994/95

Description	Western Mountains		Northern Mountains	
	MJ/Capita	Per cent	MJ/Capita	per cent
By Sector				
Rural Households	11,996	68	7,028	56
Urban Households	9,151	11	7,024	11
Commercial/Institutional	212	1	268	2
Industrial	1,358	10	1,648	16
Agriculture	201	1	236	2
Transport	1,228	9	1,335	13
Total	14,483	100	10,515	100
By Fuel Type				
Fuelwood	10,094	70	4,808	46
Other Biomass	1,003	7	1,688	16
Coal	585	4	60	1
Petroleum Fuels	1,851	13	1,926	18
Natural Gas	359	2	871	8
Electricity	601	4	1,165	11
Total	14,483	100	10,515	100

Sources: Study estimates based on HESS (1993); FSMP (1992); Pakistan Energy Year Book (1995)

In the mountain areas, biomass fuels contribute more than 95 per cent of the total energy consumed in rural and 60 per cent of that in urban, households. Thus with an increasing rate of urbanisation the consumption of commercial energy is bound to increase. The industrial sector in the mountain areas still consumes 28 per cent of total energy in the form of biomass fuels, but the agricultural sector is dependent primarily on commercial fuels if the contribution of animate energy is not taken into account. The pattern is similar in both the mountain areas, with nominal variations.

Use of Biomass Fuels

Table 6.7 shows the annual per capita consumption of biomass fuels in the mountain areas by sector and fuel types. The average total per capita consumption is 564kg of fuelwood equivalent (664kg in the western mountains and 389kg in the northern mountains). The pattern of consumption shows two main features. First, the share of fuelwood is lower, and that of agricultural residues and animal dung higher, in the northern mountains than in the western mountains. This is the result of the higher price paid for fuelwood in the plains as well as the lack of purchasing power of rural mountain communities. Second, a higher percentage of biomass fuels is consumed by the industrial sector in the northern mountains (8% versus 3%) as a result of the greater number of cottage industry activities .

Table 6.7: Biomass Energy Consumption Patterns in the Mountain Areas of Pakistan, FY 1994/95

Description	Western Mountains		Northern Mountains	
	kg/capita	per cent	kg/capita	per cent
By Sector				
Rural Households	704	87	387	83
Urban Households	380	10	221	9
Industrial	19	3	79	8
Total	664	100	389	100
By Fuel Type				
Fuelwood	607	91	290	74
Charcoal	0	0	2	1
Agricultural Residue	5	1	54	10
Animal Dung	87	8	87	15
Total	664	100	389	100

Sources: Study estimates based on HESS (1993); FSMP (1992); Pakistan Energy Year Book (1995).

Use of Commercial Energy

Table 6.8 shows the annual per capita consumption of commercial fuels in the mountain areas by sector and fuel types. The total annual per capita consumption of commercial fuels in the mountain areas is 3,842 MJ (3387 MJ in the western mountains and 4019 MJ in the northern mountains) of which 70 per cent is provided by petroleum fuels and electricity. The different sectors have a similar pattern of consumption in both mountain areas. Of the total petroleum fuels, only 10 per cent is consumed in the household sector, while 69 per cent is consumed by the transport, 15 per cent by the industrial, and four per cent by the agricultural sector. The industrial sector consumes about 35 per cent of total electricity, while the rest is consumed by the household sector (26% rural and 10% urban), and agriculture (15%). The agricultural sector in the western mountains has a higher consumption of electricity, mainly as a result of pumping ground water.

In rural households, the main contributors among commercial fuels are electricity (66%) and petroleum fuels (34%), whereas urban households mainly use natural gas (65%) and electricity (21%). The share of natural gas in the urban areas of the western mountains is higher as a result of its availability. The industrial sector in the western mountains mainly uses coal (41%) and electricity contributes 16.5 per cent, whereas in the northern mountains electricity contributes about 24 per cent and coal

Table 6.8: Commercial Energy Consumption Patterns, FY 1994/95

Description	Western Mountains		Northern Mountains	
	MJ/capita	Per cent	MJ/capita	Per cent
By Sector				
Rural Households	239	6	558	12
Urban Households	2,810	15	3,332	14
Commercial/Institutional	212	6	268	6
Industrial	1,044	31	1,164	29
Agriculture	201	6	236	6
Transport	1,228	36	1,335	33
Total	3,387	100	4,019	100
By Fuel Type	Unit/Capita		Unit/Capita	
Coal (kg)	23	17	2	2
Petroleum Fuels (kgoe)	58	55	45	47
Natural Gas (cu.ft.)	726	11	864	22
Electricity (GWh)	218	17	324	29
Total		100		100

kgoe = kg of oil equivalent

Sources: Study estimates based on HESS (1993); FSMP (1992); Pakistan Energy Year Book (1995).

only 3.5 per cent. The agricultural sector in both mountain areas uses mainly electricity (68-71%) and petroleum fuels (29-32%). All these patterns reflect the prevailing supply situation in the mountain areas. Electricity and kerosene are the two most commonly used 'commercial' fuels in both areas. In the NWFP 85 per cent of households in urban areas and 61 per cent in rural areas are linked to the electricity grid. The corresponding figures in Balochistan are 36 per cent for urban and 23 per cent for rural households. Kerosene oil is used by 90-100 per cent of households in both rural and urban areas of the NWFP and Balochistan. Kerosene oil is used by the majority of households (mostly rural) for lighting purposes. Some households also use it for cooking. The type of fuel used is influenced by the disposable income of the user. In urban areas, the share of traditional fuels used is 77 per cent in low income households and 34 per cent among high income households.

6.3.2 Unsustainable Trends in Energy Supply and Demand

Fuelwood

The total potential sustainable supply of fuelwood from existing forests in Pakistan is 6.4 million cu. m. per year (39% of the present total consumption), of which almost 92 per cent is in the northern mountains. In the northern mountains taken on their own, the supply exceeds the demand by a factor of 1.6. But the total available supply shows a shortfall of almost 30 per cent in terms of meeting the national demand. Fuelwood is still being extracted from the northern mountains to meet the national demand as it fetches a good price in the plains. In the western mountains the supply of fuelwood falls short of the demand by almost 80 per cent, and fuelwood is imported from other provinces of Pakistan.

In the past (during 60-80s) large-scale felling of forests occurred in almost all accessible mountain areas to supplement the national revenue, but regeneration of forest resources did not receive priority for investment. At the same time, the resources and revenue went to the plains, and there was little or no benefit to the mountain communities.

Fuelwood from forests still remains the main source for fulfilling newly-created demands for energy (for incoming tourists, road construction, and cottage industry). No consideration has been given to considering energy technological intervention, to expanding the supply base of the energy resources, or to the cost of afforestation. Neither new tourist destinations nor new cottage industries consider availability of energy as a constraint. The cost envisaged for fuelwood extraction from the forest is the opportunity cost of collection rather than the real resource cost. The time spent by women and children to gather fuelwood for cooking and heating also has a substantial social impact in terms of the opportunity cost of lost time that could have been spent in productive activities or self improvement.

Fossil Fuels

The potential supply of oil from the recoverable reserves in mountain areas is only 1.5 per cent of the national potential, therefore oil resources cannot be considered as a potential fuel in the context of the mountain areas of Pakistan. Preliminary estimates indicate that about 20 per cent of the recoverable reserves of gas are in the western mountains, although the scattered habitats and the heavy investment required for a gas pipeline to connect the rural population of Balochistan makes the exploitation of these resources to benefit the mountain community a Herculean task. The present practice of using this resource to meet the energy demand in the plains makes more sense. In the mountains natural gas can only really be used to generate power and as a feed material for fertilizer production. At the present rate of production, the recoverable reserves in Balochistan will only last for about 12 years.

Estimates indicate that the mountain areas possess only about three per cent of the national coal reserves, and that these will last for about 30 years at the present rate of extraction.

Large-scale Hydropower

The northern mountains possess a great potential for hydropower development, although only about 15 per cent has been exploited. Hydropower can be considered a clean source of energy, although its development may raise other environmental issues such as resettlement, soil erosion, and sedimentation.

Renewable Energy

Although there are no exact data available on the extent and nature of new and renewable energy resources in the mountain areas, data on the number of sunny days and some measured insolation values indicate a high potential for solar energy. And the occurrence of hot springs all along the Indus and Balochistan basins indicates a potential for commercial exploitation of geothermal energy both for power generation and for low heat applications, primarily for tourists. There is a possibility for exploiting wind potential in some gorges and valleys in the mountains, but further investigation is needed. The contribution of decentralised electricity (mini- and micro-hydropower, solar photovoltaic power) has been insignificant so far in meeting household lighting and motive power requirements (World Bank 1989).

Potentially the mountain areas are comparatively advantageous for renewable energy development, but development has remained marginal. There are no programmes to promote high-value energy-intensive, agro-based or skill-based commodities. Hence, no technological or institutional innovations have taken place in the energy sector.

The conventional wisdom that the deteriorating quality of forest can still be reversed prevails widely among decision-makers and planners. This is with the provision that non-renewable fossil fuels are used to replace the current consumption of biomass fuels (See Box 6.1), rather than promoting the development of renewable energy resources and technologies.

6.4 Renewable Energy Technologies

There are a number of renewable energy technologies in operation in the mountain areas; the main ones being water mills, mini- and micro-hydropower, biogas plants, and improved cooking stoves. These technologies mostly use local material and manpower resources. The efficiency and cost figures for different types of RETs are shown in Table 6.9. The infrastructure for manufacturing renewable energy related devices is poor in the HKH region. Most of the end-use devices used in households in the region are made in Punjab and Sindh.

6.4.1 Water Mills

The mountain regions have a large number of small perennial streams that are exploited by local people in many ways. These streams bring irrigation water to the fields, and, since agricultural plots are small in the hilly terrain, the small streams

Box 6.1: The Coal Briquette Programme - The Question of Sustainability in the Mountains

The PCSIR Fuel Research Centre in Karachi has developed a process for making processed coal briquettes to use low rank, low grade, high sulphur indigenous coal. The use of processed coal briquettes is environmentally safe and non-hazardous. More than 200 tonnes of briquettes have been produced so far by PCSIR and supplied mainly to poultry farms for space heating. These briquettes have also been transported to Skardu in the Northern Areas where they have been tested on a pilot scale in rural households for cooking and space heating. The briquettes have been shown to withstand transport stress and the product was acceptable to the local population. The landed cost of briquettes in Skardu is estimated at around Rs 6.00 perkg – including the transportation from Karachi to Skardu (transportation consumes imported oil). Wood is being sold at Rs 2 to Rs 2.5 perkg depending upon the quality of the firewood. It would therefore be necessary to provide a lot of subsidy for coal briquettes in order to encourage local residents to use them. The government has shown its readiness to provide the product at subsidised rates in order to check the trend of cutting fruit trees. But the question of financial sustainability still remains unanswered. It may be worthwhile to look for other alternatives that exist within the mountains. It is also important to remind ourselves that for any programme to be successful in the long-term, it is essential for it to be environmentally and economically sustainable. This example looks fine with regard to environmental sustainability, but financial sustainability is a big question mark.

Source: Fuel Research Centre, PCSIR

provide adequate water for this purpose. Water from streams can also be used in households for drinking and cooking, depending on the quality. Traditionally, the energy from flowing streams has been used to obtain motive power by installing water mills on site. These mills are used mainly for grinding wheat and maize. The mills consist of a wooden turbine with a large number of straight wooden blades fitted to a wooden shaft. Water from the main stream is diverted to the mill through a water chute, generally an open channel made from wooden planks or carved from a tree trunk. The mills have two grinding stones - the lower one fixed and the upper stone rotating at a speed of 100-150 rpm. The mill operates at an efficiency of 15-25 per cent. It requires frequent replacement of turbine blades.

There are thousands of these traditional water mills all over the HKH area of Pakistan. No data are available on the estimated potential of these mills. The mills are under the control of local technicians who have learned the technology from their forefathers. No systematic effort has been made to examine the possibility of improving the mills.

Table 6.9: Efficiency and Cost of RETs in Pakistan

Technology	Efficiency	Cost (PRs)
Water Mills	15-25%	2,000
Mini- and Micro-hydro	40-50%	10,000-20,000 per kW
Biogas plants		5,000 (3 cu.m. plant)
Traditional Stoves	6.5%	
Improved Stoves	14-28%	

6.4.2 Mini- and Micro-hydropower

The North-West Frontier Province is rich in hydro potential. The site potential for electric power varies from the micro to the mega range. Mini- and micro-hydropower are especially suitable for the mountain areas in less developed countries as a way of meeting the basic need of rural communities for electricity. Such plants can be designed and fabricated with less sophisticated technology than large plants. Transportation of small plants to remote and inaccessible areas is easy. The smaller plants offer greater opportunities for local people to participate in their implementation, operation, and maintenance.

There are thousands of small capacity sites located throughout the mountains of Pakistan. Thus, the potential for hydro-electricity could be exploited quite extensively. The Pakistan Council of Appropriate Technology (PCAT) is a pioneer agency initiating work on this. The PCAT has so far installed more than 150 micro-hydro-electricity plants in the range of five kW to 30kW. The cost of installation is in the range of PRs 10,000 to 20,000 per kW depending on the site condition and plant capacity. Local people and PCAT staff work together closely right from identification of the site to installation of the plant. The PCAT provides the hardware and technical assistance, and local people provide labour and local materials. The local population agrees to complete the entire civil work necessary before the machinery is shifted to the site. They are responsible for purchasing and installing distribution wires. After the plant becomes operational, it is handed over to the community. They are responsible for its operation and maintenance throughout the life of the plant. Representatives of the community form a 'Management Committee' for the plant which makes decisions on such things as who should receive an electricity connection, what tariff should be charged, and how it will be collected.

Although the plants are installed primarily in order to produce electricity to meet the lighting needs of the community, small agroprocessing units (flour grinding, rice husking, cotton ginning, saw mills, etc) are installed in the power house in several locations. These units are operated directly from the shaft power of the turbine during the day when electricity is not required for lighting.

6.4.3 Biogas Plants

Biomass is the oldest and most fundamental source of renewable energy, and mankind has been using it for millennia. It can be converted into a variety of fuels such as solid fuel (fuelwood, charcoal), liquid fuel (oil, alcohol), and gas (methane and hydrogen). Biogas plants are simple and economical devices for converting dung into combustible gas and providing organic fertilizer as a residue. There are a large number of cows and buffaloes in Pakistan and thus a tremendous potential for biogas technology. Biogas provides clean energy and a better environment in the house, giving relief to rural women from smoke.

A number of agencies in Pakistan, mainly the Directorate General of New and Renewable energy resources (DGNRER) and the PCAT have installed biogas plants all over the country including in the HKH areas. The PCAT initiated a programme of dissemination of biogas plants in 1978-79, adopting the Chinese design of digester. The performance of this digester was not good and later the PCAT adopted the Indian design, with some modifications to bring down the installation cost without lowering the efficiency (PCAT 1991). The PCAT provides technical guidance and supervision free of cost, while the cost of such things as materials and construction is borne by the beneficiaries. The cost of a single family size plant of three cu. m. per day capacity based on four to five animals is about PRs 5,000 (PCAT 1991).

6.4.4 Improved Cooking Stoves

In both urban and rural areas of the HKH region, cooking is the main activity in the household sector that requires fuel. The traditional cooking devices used (*chula*) have both economical and ecological constraints as they are inefficient and cause problems for human health.

Several agencies are engaged in the development and distribution of improved cooking stoves. PCAT has developed improved designs of cooking stoves and cooking utensils which achieve an overall fuel saving of 40-50 per cent over the traditional design. Traditional stoves have been found to have a pot utilisation efficiency of 6.5 per cent. The improved design stoves have an efficiency in the range of 14-28 per cent. These designs are of different sizes and are constructed on site from a mixture of clay, sand, animal dung, straw, and water. They are constructed at little or no cost (ATDO 1985).

The Fuel Saving Technologies' Project of the German Agency for Technical Cooperation (GTZ) and the Government of Pakistan, based in Peshawar, has since 1991 developed several designs of fuel-saving cooking and space heating devices based on the needs of the users. Efforts were concentrated on improving the existing traditional devices. The improved stoves can be used with all kinds of biomass fuel – including wood, dung, bushes, and crop residues. Thousands of these stoves have been distributed since the start of the project (GTZ/FECT 1993).

The main constraints to a much wider dissemination of the improved stoves are: a) the high cost of metal stoves for low income households; b) the short working life (12-24 months), after which replacements are required; and c) fuelwood must be chopped into small pieces which is a laborious and time-consuming task carried out by women.

6.5 Energy Prices and Price Setting Mechanisms

The prices of oil, gas, and electricity are determined by the government at various stages which include production, transmission, distribution, and consumption. The price of indigenous coal is not controlled by the government. The price of fuelwood is subject to wide variations, depending upon such factors as the location, season, species, piece size, and moisture content. The price of different fuels is shown in Table 6.10.

The well-head price of indigenous oil is determined in accordance with the agreement made between the holders of the oil drilling lease and the Government of Pakistan. When determining the price, due regard is given to the prices prevalent in the international market, mainly the Arabian/Persian Gulf market. The government fixes the ex-refinery prices, the margin allowed to distribution companies, the inland freight margin, the development surcharge, and the sale price. The prices fixed allow a reasonable return on the investment made by the refiner, distributor, and retailer. The sale prices are uniform throughout the country except for minor variations resulting from octroi charges levied by local administrations. Whereas the margins between sale price and ex-refinery price are high for high speed diesel oil and gasoline (regular), the margin for kerosene oil is low. In June 1995, margins were 57 per cent for diesel, 33 per cent for gasoline, and 16 per cent for kerosene. It is government policy to keep the price of kerosene low as this is the main source of commercial fuel for low-income households. As an incentive for developing indigenous capabilities, new refineries based on indigenous crude will be assured a minimum rate of return of 25 per cent on the paid-up capital net of tax for eight years if set up by the year 2000 (GOP 1992).

The well-head price of natural gas is fixed by the government in accordance with the agreement made between the holders of the drilling lease and the Government of Pakistan. Purification, transmission, and distribution charges for the gas companies are also determined by the government. When fixing the prices, the government ensures that the gas companies engaged in purification, transmission, and distribution of gas make a reasonable return on their investment. Household con-

Table 6.10: Price of Major Commercial Fuels

Fuel type	Unit Price Ex-refinery	Fixed-Sale Price
Kerosene	(PRs/kl)	
- May 1985	2693.4	3300
- June 1995	5385	6250
Motor Spirit	(PRs/kl)	
- May 1985	5143.37	7150
- June 1995	10355.6	13750
High Speed Diesel	(PRs/kl)	
- May 1985	3211.4	4670
- July 1995	4135.7	6500
Natural Gas		(PRs/million cu. ft.
- May 1985		
- Industrial		39540
- Commercial		48540
- Domestic		18000 - 27000
- June 1995		
- Industrial		84050
- Commercial		94560
- Domestic		40270 - 78450
Coal	(PRs/tonne)	
- FY 1990/91		
- Sharig Mine		533.26
- Sor Range Mine		1034.73
- Makerwal Mine		899.42
- FY 1994/95		
- Sharig Mine		621.33
- Sor Range Mine		1411.96
- Makerwal Mine		929.61

Source: Pakistan Energy Year Book, 1995

sumers are charged on a sliding scale, the higher the consumption the higher the charge per unit of gas consumed. Special rates are laid down for special consumers such as fertilizer, cement, and power companies.

The price of electricity is fixed by the utilities (the Water and Power Development Authority (WAPDA) and the Karachi Electricity Supply Corporation (KESC)) in accordance with the pricing arrangement prescribed by the Government of Pakistan. The electricity tariff has the following components: a) fixed cost; b) energy charges; c) fuel adjustment charges (FAC); and d) additional surcharge. The fundamental principles for electricity prices are to ensure recovery of all costs (fixed and variable) and to enable generation of additional funds for development and expansion. Household consumers are charged on a sliding scale. Time-of-day and seasonal tariffs are applied for certain categories of consumers.

The price of coal produced by the Pakistan Mineral Development Corporation (PMDC) is determined on the basis of open tender. In the case of private mine owners, the price of coal is determined by the supply-demand situation in the market.

The Forestry Sector Master Plan team observed a variation of up to 60 per cent in the retail price of fuelwood charged by the same seller depending upon variations in species and piece size of the wood. Usually there are three marketing levels for fuelwood, each with its own price structure - producer, wholesaler, and retailer. The average retail price of fuelwood and charcoal in 1991 was PRs 1.35 perkg and PRs 3.75 perkg, respectively (Table 6.11). In 1995 the average fuelwood price had increased to PRs 1.78 perkg.

6.6 Review of Energy Policies, Programmes, and Institutions

6.6.1 An Overview of Energy Planning and Policies

National energy planning in Pakistan is the responsibility of the Energy Wing of the Ministry of Planning and Development. Energy plans are set within the framework of the national macro-economic development plan. Planning for conventional energy development is carried out by a number of ministries and public sector utilities, in particular the Ministry of Petroleum and Natural resources and the Ministry of Water and Power, the latter being responsible for the Water and Power Development Authority (WAPDA), which is the national power utility (GOP 1996).

The Eighth Five Year Plan (1993-98) aims to explore and exploit domestic energy résources; improve and expand the transmission and distribution system of energy; rationalise energy prices to promote energy conservation and to enable self-financing; and decentralize and deregulate the energy sector to promote the induction of the private sector (GOP 1992).

Demand and supply side policies and strategies have also been spelled out. On the demand side, the central thrust is for energy conservation through incentives and pricing. Similarly, the major element in the supply policies is improvement in the pricing structure of fossil fuels to reflect the border prices. At the same time, the government has also announced policy packages for promoting private sector investment in the development and transportation of indigenous oil, gas, and hydropower. The characteristics of these policies are to provide internationally competitive terms, an attractive framework for foreign investment, simplification of procedures, and creation of a domestic corporate securities' market (GOP 1992; 1995a; 1995b).

The basic principles in the plan document with regard to development of biomass energy are: i) promotion of forestry and increase in the availability of biomass; ii)

Table 6.11: Average Annual Retail Prices of Fuelwood and Charcoal

Fuel type/place	1960	1970	1980	1991
Fuelwood (PRs/kg)				
- Karachi	0.09	0.13	0.48	1.50
- Lahore	0.09	0.14	0.52	1.12
- Rawalpindi	0.10	0.14	0.52	1.62
- Peshawar	0.12	0.12	0.60	1.25
- Quetta	0.07	-	0.40	1.35
- Average	0.09	0.13	0.51	1.35
Charcoal (PRs/kg)				
- Karachi	0.16	0.40	1.36	2.50
- Lahore	0.24	0.35	1.25	-
- Rawalpindi	0.24	0.36	1.47	5.00
- Peshawar	0.23	0.30	1.67	5.00
-Quetta	0.20		0.93	2.50
- **Average**	0.22	0.35	1.37	3.75

improvement in efficiency during utilisation of biomass; iii) promotion of better utilisation and distribution practices for crop residues; and iv) improvement in the market structure for fuelwood and crop residues. At the same time, the Forestry Sector Master Plan (FSMP) emphasises growing more wood by planting trees on private land and reducing fuelwood consumption by using it more efficiently and replacing it with energy efficient, environmentally sound, and economically viable alternatives. The FSMP also proposes various programmes for each province. Box 6.2 gives a summary of the proposed programmes that are relevant to mountain areas. However, it is not clear whether these proposals have been approved.

The plan document does not recognise the (potential) role of other sources of renewable energy (solar, wind, biogas, and geothermal) in the mountain areas. Policy statements on renewable energy resources are limited to: a) demonstration and utilisation of solar energy in remote areas; b) initiation of a wind energy resource programme; c) consideration of exemption from tax and duty for imports of renewable energy technologies; and d) investigation and development of small and micro-hydropower projects by provinces to meet local electricity demands.

Energy development in mountain areas is dominated by the extension of grid electricity and petroleum product supplies to rural areas. These efforts are planned and managed by various departments of the federal and provincial governments and are integrated into the national development plan as part of the overall development planning. However, no special effort has been made to formulate energy plans for the mountain areas as such.

Box 6.2: Summary of FSMP Programmes, 1992

Province	Programme Title
NWFP	I) Protecting and Developing Watersheds; II) Intensifying Management of Upland Coniferous Forests; III) Planting on Farmlands; IV) Amenity Planting; V) Private Planting on Non-forest Public Land; VI) Protecting Arid Rangelands; VII) Planting in FATA; VIII) Protecting and Managing Wildlife and Biodiversity; IX) Strengthening Administration, Education and Training, and Research
Balochistan	I) Protecting and Developing Watersheds; II) Stabilising Shifting Sand Dunes; III) Protecting Arid Rangelands; IV) Preserving Juniper Forests; V) Protecting and Managing Wildlife and Biodiversity; VI) Planting on Farmlands; VII) Strengthening Administration, and Education and Training
AJK	I) Protecting and Developing Watersheds; II) Intensifying Management of Upland Coniferous Forests; III) Protecting and Managing Wildlife and Biodiversity; IV) Strengthening Administration, Education and Training, and Research
Northern Areas	I) Intensifying Management of Coniferous Forests; II) Protecting and Developing Watersheds; III) Planting on Farmlands; IV) Protecting and Managing Wildlife and Biodiversity; V) Strengthening Administration

Source: FSMP (1992)

6.6.2 Energy Programmes and Institutions

Biomass Energy

The government has jurisdiction over 6.88 million ha of land classified as public forests or rangelands. About 3.62 million ha of additional forest land are community-owned and under some degree of government control. There are different legal classes of government forests relating to some extent to the existence of public use rights: I) State Forests (1.27 million ha) in Balochistan and AJK (these fall under a different forest regulation); ii) Reserved Forests (0.64 million ha), declared under the Forest Act in Punjab, Sindh and NWFP and owned by the government, people living nearby have few legal rights to these forests; and iii) Protected Forests (4.72 million ha) in all provinces and the Northern Areas, these provide full local rights for collecting forest produce and grazing (FSMP 1992; PNCS 1993).

There are a number of non-public forests that come under various degrees of government control: i) Guzara Forests (0.55 million ha) in the NWFP (Hazara District) and Punjab (Murre-Kahut) are village lands that were not declared Reserved or Protected Forests at the time of land settlement (they are owned by families, or groups of families, and are either managed by the Forest Department or, since 1981, by forest co-operatives); ii) Communal Forests (2.98 million ha) in the Northern Areas (they were once owned by local rulers but freely used by local people, and are now controlled by the Forest Department); and iii) Privately Owned Forests and Plantations (0.2 million ha) (these include land being planted by the Forest Department under various projects, predominantly for watershed management) (Crabtree and Khan 1991; Ashraf 1992).

At present, forestry is a provincial subject, with some responsibilities, such as training and research, remaining with the federal government. The forestry sector is administered by the Ministry of Food, Agriculture, and Cooperatives through the office of the Inspector General of Forests (IGF), which is responsible for matters relating to national forest policy and coordination between provinces. The forestry sector is administered primarily by the Forest Departments of the provinces. Their major responsibilities include: protecting and managing existing forests to fulfill local needs for fuelwood, timber, and fodder; establishing and managing plantations on public lands; promoting tree-planting on private land through social/farm/agroforestry programmes; improving watershed and rangelands; and promoting and developing tourism (in AJK only). The responsibilities may vary according to the conditions and needs (FSMP 1992; Dijk and Hussain 1994).

Commercial Energy

At present, there are three oil refineries operating in Pakistan (Attock Refinery Ltd., Pakistan Refinery Ltd., and National Refinery Ltd.), mainly in the plains. The transportation of oil is carried out by road (54%), pipeline (31%), or rail (5%) depending on the terrain.

Two companies (the Sui Northern Gas Pipeline Limited and Sui Southern Southern Sui Gas Company Limited (SSGC)) control the transportation of gas by managing a 5,278km long mains and loop pipeline system and a 41,063km long distribution network serving about 2.4 million consumers. The distribution of natural gas is the responsibility of the two state owned gas companies. Shares in these companies are now held by both the private and the public sector. The main supplier of LPG in the western mountains is the SSGC which has its own bottling plant in Quetta. Until recently SSGC relied on indigenous LPG, which was shipped in bulk tankers to Quetta. The suppliers in mountain areas transport bottled LPG. Kerosene is distributed through the major oil companies and downwards through street vendors and small shops. Apparently there are no problems of supply and availability even in far-flung areas, although the final retail price may be slightly higher than the fixed price (Raza and Sherer 1995; Khan et al. 1995).

WAPDA is the principle organization involved in the generation and distribution of electricity in mountain areas, besides serving the whole country (WAPDA 1995, 1996). There are about 1.4 million consumers in the NWFP and 2.2 million in Balochistan, about 40 per cent of the total consumers of electricity in the country. At present, 8,299 villages in the NWFP and 2,314 in Balochistan receive electricity through the WAPDA system. The shortage of electricity in the mountain areas is indicated by the 24,139 household applications pending and the frequent load-shedding (WAPDA 1995; 1996).

A Small Hydroelectricity Development Organization (SHYDO) was established by the NWFP Government in 1986. The principal task assigned to this organization was preparation of a Master Plan and identification of all the available potential for small hydroelectricity schemes. The name of the organization has now been changed to Sarhad Hydroelectricity Development Organization (SHYDO), and it has a broader mandate to implement and execute larger hydroelectricity schemes instead of smaller ones.

Rural Electrification

WAPDA's Rural electrification Office is responsible for planning and implementing rural electrification programmes. The principal approach to rural electrification is grid extension, that is the electrification of villages in close proximity to the grid. A village is considered electrified when 40 per cent of its population is provided with electricity in the first year and the remaining population is covered subsequently at an annual rate of increase of 10 per cent. In recent years, the rural electrification policy has shifted from greater village coverage to more intense consumer saturation in villages already electrified (PGOB 1995; WAPDA 1996b).

This rural electrification approach based on grid extension appears to be unfavourable, as the load characteristics of rural consumers in the mountains are different from those of urban consumers, and the technical and administrative options that can be used cost effectively to serve these consumers differ from those for other consumers. For example, the load factor in mountain areas varies from 10 to 30 per cent whereas the overall national load factor exceeds 60 per cent. Because of low load factors, low demand, high power losses, high revenue loss, and the prohibitive cost of transmission and distribution lines, the extension of the electricity grid in mountain areas becomes a burden on the national exchequer. In addition, the ability of consumers to pay for electricity is less than the national norm, and even the official and unofficial costs involved in getting a connection are so high and cumbersome that consumers cannot afford them and remain without electricity even in electrified areas. Indigenous renewable energy resources and technologies thus offer a promising alternative for the mountain areas of Pakistan.

Renewable Energy Systems

The programme on solar photovoltaics is the responsibility of the Director General Office of New and Renewable energy resources (DGNRER) which is at present non-functional (Pakistan Energy Year Book 1995). Recently, however, the Pakistan Council for Appropriate Technology (PCAT) successfully developed and demonstrated a parabolic type concentrated solar cooker that can boil water within four minutes and can cook all types of traditional Pakistani foods such as chapatis, fried foods, and curries (private communication, PCAT). Only minimal efforts have been directed towards developing passive solar building technologies in mountain areas of Pakistan. ICIMOD has recently initiated an activity with the Aga Khan Housing Board of Pakistan (AKHBP) to review the state of the art of this technology to identify further areas for work.

At present, PCAT has the responsibility for disseminating fuel-efficient cooking stoves under various projects assisted by GTZ and the Government of Pakistan in various parts of the NWFP (private communication, PCAT). The DGNRER and PCAT are both responsible for the installation of biogas plants all over the country, including mountain areas.

The Pakistan National Conservation Strategy (NCS) document (1993) outlines seven priority programme areas of activities for developing and deploying renewables in Pakistan (PNCS 1993). However, none of the projects identified in the NCS have been implemented except PCAT's micro-hydropower (MHP) project and some initiatives taken by the Forest Department of the NWFP for wood plantation. The PCAT's MHP project was not funded by NCS but initially by the Public Sector Development Programme and then by the Technology Development Action Plan (TDAP). The National Technology Policy and TDAP approved by the Government in 1993 included seven projects on promoting new and renewable energy technologies (MOST 1993). None of these projects has been implemented, however, and some (MHP and Fuel Saving Technology) which were initially funded and approved by TDAP, are now facing financial constraints with no allocation for these projects to continue their activities in the financial year 1997.

Ten high priority national projects on renewable energy with a funding requirement of 10 million PRs were presented at the World Solar Summit in 1996 (UNESCO 1996). It is proposed to implement many of these projects in mountain areas of Pakistan. The Ministry of Science and Technology (MOST) is seeking assistance from donors for implementation of these projects, although it will be quite difficult to arrange local counterpart funding. At present the DGNRER is non-functional and there is no policy on renewable energy in Pakistan. Recently a proposal was submitted by MOST to create a new Council for Renewable energy Technologies (CRET) by merging PCAT, the National Institute for Silicon Technology (NIST), and the Solar Energy Centre of PCSIR.

6.6.3 Economic and Environmental Effects of Energy Policies and Measures

The policies and measures related to development of the energy and forestry sectors that have resulted in positive and/or negative economic and environmental impacts in the mountains of Pakistan are summarised in Box 6.3.

There are many examples of an overall negative impact of policies and measures. The underpricing of natural gas has reduced the resource life of this fuel. At the same time the resource is being used by the sector which offers low value addition. Similarly, underpricing of electricity during the eighties led to a rapid increase in demand which resulted in greater reliance on thermal generation and subsequently high emissions of pollutants. In contrast, measures such as boiler efficiency improvement programmes and free auto tune-ups have reduced environmental emissions and reduced the energy to product ratio.

Policies to promote forestry and energy development in the mountains were initially geared towards reducing the consumption of fuelwood through the introduction of improved cooking stoves. These interventions failed as a result of the absence of any proper evaluation of the multiplicity of traditional technologies and the socio-cultural context of the mountain population. At the time consumption of fuelwood was considered to be the primary cause of deforestation. Other factors, such as the requirement for fodder for livestock, need to use the land for cultivation because of low productivity, and large-scale felling of timber, were never given due attention when designing energy technology options to suit local conditions. Equally, alleviation of human drudgery and deteriorating health conditions, particularly of women and children, as well as the problem of decreasing soil fertility, were never considered seriously.

Rural electrification has always emphasised fulfilling the lighting needs of small towns in peripheral areas, rather than providing the motive power that could lead to economic transformation of the mountains. Electrification was considered a welfare package with the price of electricity always subsidised (Ramani 1995 et. al. 1995; Rijal 1996).

Energy planning investments have been mostly biased in favour of large schemes and emphasis has always been placed on the expansion of the supply rather than on the potential of energy demand management. There are no adequate policies to promote decentralised renewable energy systems or end-use appliances (PNCS 1993).

Box 6.3: Energy Sector Policies and Measures and Their Environmental and Economic Effects

Sector	Type of Policy and measure	Environmental Effects	Economic Effects
Fossil Fuel	Boiler efficiency improvement Free auto-tune-ups; conservation measures in factories	Reduced environmental emissions	Reduced energy/product ratio; increased profits
	Development of Lahkra Coal by fluidised bed technology	Lower sulphur emissions than conventional combustion	productivity increase in agriculture; economic performance better
	Underpricing of natural gas (1955-89)	Resource life now less than 12 years	Resource exploited for lower value-addition
Electricity	Underpricing electricity Policy on Rural Electrification	Rapid demand led to greater reliance on thermal generation; High emission factors and environmental impact of production	Load-shedding and loss of industrial production Excessive demand
Hydropower	Policy to promote	Displacement of people ecosystem change; human displacement; risk of reservoir-induced seismicity and dam failures	Burden on the economy High social cost to the economy
Forestry	Seasonal tree plantation (1950 onwards) Concessions Policy (contract policy pre 1947-1980s) Efficient cooking stove promotion	Improved ecology/landscape; Over harvesting destroyed watersheds; destruction of downslope agriculture Reduced indoor pollution	Positive effect on crop yields; increase in income, low productivity; high cost to economy. High financial burden for the consumer
Farm energy	Forestry Policy (1980s) Tarbela watershed protection (1980s)	Improved marginal land for farmers; mono-plantations of slow growing chir pine only; reduced erosion	Increase in income Reduced economic life dam
Renewable Energy	Lack of policies to develop renewable energy sources	Indoor carcinogens; increased use of other biomass; reduced organic matter	Decrease in agricultural productivity; high health costs

Sources: Modified and adapted from Pakistan NCS Report (1993); SPCS (1996).

6.7 Environmental Implications of Energy Use

The household sector in Pakistan consumes nearly half of the total energy used in the country. The greatest proportion of the energy used in households is derived from wood and other biomass resources such as animal dung and crop residues. This is also true in the HKH areas; cooking, space heating, and heating of water are all carried out using fuelwood. The efficiency with which biomass is used as energy is very low for most operations (10%-13%). This has led to overuse of the biomass resource contributing to deterioration of the environment. Burning of biomass in traditional cooking stoves is highly inefficient and produces gases that are harmful to human eyes and lungs. Fuel collection is a important responsibility for women in rural areas. Up to five hours may be spent on fuel collection and cooking by women every day. With increasing scarcity of free fuelwood, women have to walk longer distances. Children, especially girls, assist their mothers in fuel collection and cooking. This has an adverse effect on their schooling. The use of biomass fuels has a number of other undesirable consequences including a) deforestation, the most serious consequence; b) loss of fertility of agricultural land as a result of the use of dung and crop residues as fuel instead of as fertilizer; and c) health hazards to households as a result of the use of low quality fuels and subsequent emission of smoke and gas.

Table 6.12 shows the change in forest cover in Pakistan from 1880 to 1980. Over a period of 100 years, the forest area decreased to less than half (Table 6.12), with the rate of loss increasing in the recent past. This deforestation trend raises the question of the sustainability of the biomass resource in the context of meeting the household demand for energy. Deforestation has many negative effects – including the inducement of flooding and siltation downstream, reducing the lifespans of water reservoirs. The use of dung and crop residues as fuel has deprived agricultural land of natural fertilizers, and the widespread use of chemical fertilizers is adversely affecting the environment.

Table 6.12: Change in Forest Cover in Pakistan

Year	Forest Area (sq.km)
1880	141,530
1900	132,690
1920	119,920
1940	108,400
1960	90,510
1980	67,310

Source: HESS 1993

Hydropower is the main potential source of electricity production in the NWFP. Already there are a couple of hydro stations operating in the province. Several other schemes are at various stages of planning and implementation. These structures can have adverse effects on the environment, however, including displacement of local people, cutting of trees, promotion of water-borne diseases and parasites, disturbance to aquatic organisms, and sedimentation. The two main reservoirs in the NWFP - Warsak and Tarbela - are silting up at a rapid rate, and it is feared that the working life of these reservoirs may be greatly reduced. If this happens, the water supply for irrigation systems will be reduced as will energy production from the hydropower stations.

Long distance, high voltage transmission lines are being laid to electrify villages in the NWFP and Balochistan. This leads to displacement of local populations along the right-of-way. There is also a potential risk to humans from the high electromagnetic fields associated with high voltage lines.

The province of Balochistan produces a substantial amount of coal (half of the total production in the country) which is used mainly in the brick-kiln industry and for power generation. During 1994-95, nearly 1.6 million tonnes of coal were produced in Balochistan. Coal mining can have a number of negative impacts on the environment such as land disturbance, emission of dust, acid mine drainage, and pollution of streams and rivers. It also has a negative impact on the health of miners and appropriate safety measures should be taken. The locally produced coal has a high sulphur content (more than 5%) and low heat value.

In order to improve the productivity of agricultural land in mountain areas, efforts are being made to diversify the agricultural sector, and this will increase the energy requirement. The increased level of energy production, consumption, and distribution will add adversely to the numerous causes of overall degradation of environmental conditions.

Combustion of fossil fuel, burning of biomass, and deforestation are believed to be the main contributors to the greenhouse effect. Carbon dioxide, methane, and nitrous oxide, the main greenhouse gases, are emitted during burning of biomass, the main fuel in the HKH region of Pakistan. The emission from the HKH areas may be modest on a global level, but they could rise rapidly in future as a result of the high rate of population growth and concomitant increasing demand for biomass fuel.

6.8 Findings of the Study

The mountain areas have special characteristics such as varied topography, seasonal variation, climatic conditions, remoteness, and inaccessibility. These characteristics influence the pattern of energy consumption in all sectors. The supply and consumption pattern is quite different from that in the plains. At the same time, the socioeconomic level of the people living in the mountain areas influences the energy use pattern.

The reported data was derived from the available literature. While reviewing the existing literature on the subject, it became clear that there were no reports covering the overall energy situation in the HKH areas of Pakistan separate from the rest of the country. The Energy Year Book published annually by the Government of Pakistan only contains data on the supply and consumption of commercial fuels. Data are mainly at national level, with some data at provincial level. There is no report available which deals specifically with data and issues in the HKH region of Pakistan. The available data are aggregated at national and provincial levels and may not reflect the true position of the hill communities. No authentic data are available for the pattern of energy consumption and supply in FATA.

Biomass - fuelwood, agricultural residues, and animal dung - is likely to remain the most appropriate fuel for most people in the mountain regions for decades to come. Adequate policies should be framed and programmes implemented to increase the production and supply of these fuels. Appropriate species of fast-growing trees may be planted wherever feasible. Local communities should be encouraged to participate in and manage such projects. Biogas plants suitable for operation in the climatic conditions of the area concerned should be promoted. Due emphasis should be given to demand-side management. The efficiency and performance of end-use devices (such as cookers) should be improved. For this, it may be necessary to undertake R&D work at appropriate institutions. NGOs may need to be involved in the dissemination of improved technologies.

Electrical energy is the best way of providing lighting and motive power. But extension of the grid may not be the best means of supplying electricity to communities living in remote mountainous areas. Decentralised generation may be a better option for most of these places. Such generation could be based on micro- and mini-hydropower plants using locally available sources of water. The feasibility of running small power stations with wood or coal as a source of fuel could be examined. Solar-energy and wind-energy devices are still expensive and complicated in design and maintenance. These devices will not find wide-scale application in the immediate future. However, R&D efforts should be strengthened to consider the future potential of such sources. Institutions such as PCAT and PCSIR should be fully supported in their programmes on use of renewable energy.

The use of coal in the household sector is negligible. There are large deposits of coal in the country, and an effort is required to promote the use of coal in the household sector. The locally produced coal is of inferior quality and has a low heat value and high sulphur content. R&D is required to make the coal more appropriate for household use. Options for using coal briquettes as a substitute for fuelwood should be evaluated.

The institutional arrangements for policies and programmes related to energy supply in the HKH region of Pakistan need rethinking. The special characteristics of the mountain areas, such as topography, climatic conditions, remoteness, and inaccessibility, influence the pattern of energy demand in all parts of the region. The supply and demand pattern for energy could be quite different from that in the plains. The establishment of a special cell in the power and energy departments of the Planning and Development Departments in the provinces (NWFP and Balochistan) to deal with energy issues in mountain areas may be instrumental in promoting RETs. There should be increased involvement of local institutions, such as District Councils, in the planning and implementing of energy projects.

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Vertical shaft brick kiln near Peshawar, Pakistan

Improved cooking stoves installed in a household in the Northern Areas, Pakistan

Chapter 7

Approaches and Strategies for Sustainable Energy Development in the Mountains: An Agenda for the Future

by
Kamal Rijal

7.1 Emerging Energy Issues in Mountain Areas

7.1.1 Unsustainable Patterns of Energy Supply and Demand

The main sources of renewable energy used at present in the HKH region are biomass fuels (50-90% of total energy) and hydropower (1-5% of total energy), but the potential supply of hydropower constitutes 70 to 90 per cent of energy potential in the region and biomass only between 10 and 30 per cent. Thus there is an imbalance between the supply and demand structure for energy. There are several reasons for this including: a) high capital investment is required for hydropower development; b) the main energy demand is for low grade energy, i.e., heat energy; c) the financial cost of fuelwood extraction is much lower than the social cost; d) the opportunity cost of fuelwood collection is very low as a result of the lack of employment opportunities in the mountains; e) the availability of subsidised petroleum fuels; and f) lack of efficient and reliable renewable energy technologies (Rijal 1997a). At present, the choice of a particular type of energy to fulfill a demand is dictated primarily by financial viability. No consideration is given to environmental or social cost, or even to long-term sustainability of the supply. There is a need to formulate policies that promote a shift in the existing energy supply mix so as to reflect the energy supply potential available within the HKH region of each country. The policies and role of the governments concerned should be instrumental in minimising the differences between financial and environmental viability, which in turn will lead towards optimal allocation of resources taking into consideration the costs to both society and the environment.

In most of the HKH region, the demand for fuelwood exceeds the sustainable supply. This is the result of the rapid thinning of forests closer to settlements resulting from a lack of appropriate management practices, the lack of suitable technologies to meet cooking and heating demands, the increasing demand for fuelwood to meet the needs of incoming tourists and emerging cottage industry activities, and the increasing demand for high grade energy. Box 7.1 gives a few examples illustrating this situation.

The main concern in the HKH mountains is to make production of fuelwood renewable rather than to restrict the use of it, since the possibilities for energy substitution are limited as a result of the specific conditions in the area. Various modes of afforestation, such as community forestry, social forestry, and leasehold and private forestry, are being promoted within the region, but they mostly lack appropriate institutional mechanisms to address ownership issues and thus suit local conditions.

There is a general tendency for users to shift towards using higher grade energy forms as their living conditions improve. No serious effort is being made to develop technologies that can upgrade the quality of biomass fuels. At the same time, the possibility of developing and producing green energy, for example, through the extraction of oil (jatropa, 'chiuri' butter) and alcohol fuels has remained marginal in terms of research and development. In the HKH region, development of micro-hydropower has been considered primarily as a way of fulfilling the illumination needs of mountain communities, and the possibilities for linking it with the productive sector in order to improve the economics of power production have been neglected.

7.1.2 Inharmonious Energy Transitions

There are two distinct phenomena apparent in the HKH mountain areas. First, there is a movement from fuelwood towards other non-monetised low quality energy forms. This has happened because the cash resources of the mountain population and their willingness to pay are low, if fuelwood is scarce most of the population start consuming 'other' biomass fuels for which the associated cost is only that

Box 7.1: Examples of Unsustainable Patterns of Energy Supply and Demand

In Nepal overall, only about two-thirds of the demand for fuelwood are met by the sustainable supply. The fuelwood balance at district level varies. There is a surplus of fuelwood in some districts in Western Nepal, but it is in short supply in the central hills. In Pakistan, the total sustainable supply of fuelwood is less than 40 per cent of the total demand, and more than 90 per cent of the supply is in the Northern Mountains (NWFP, FATA, AJK, Northern Areas). In the Northern Mountains alone the fuelwood supply exceeds demand by a factor of 1.6. However, fuelwood is extracted to meet the demands of the plains where it fetches a good price. Traditional stoves are effective as heating devices but less efficient for cooking. The direct smoke emissions are a health hazard for household members. The improved stoves disseminated in Nepal were efficient in terms of pot utilisation, but were not suitable for meeting the room heating requirements of mountain households. There are several locations in Nepal, India, and Pakistan where tourism is being promoted. The energy demands of tourists are high compared to those of local residents. Most of these demands are in the form of heat energy and are being met by fuelwood in the absence of appropriate information and because of the prohibitive cost of RETs. Increased agricultural and cottage industry activities leads to greater demands for both heat energy and motive power which require high-grade mechanical and electrical energy. The energy options available for the provision of high grade energy are limited.

Sources: Rijal 1997a; Bansal 1997; Banskota and Sharma 1997; Abdullah 1997; Mengjie et al. 1997

of labour for collection. Second, there is a trend towards use of non-renewable fossil fuels. This is because those mountain people who can afford to pay for energy services tend to buy commercial fuels such as kerosene and LPG, partly because there are no reliable renewable energy technologies available as an alternative. The main factors aggravating these trends are:

- price distortion - the price of fuelwood even when it is marketed does not reflect the real cost of the resource. The cost reflected is the collection cost, which varies widely from location to location depending on the opportunity cost of labour; subsidies on commercial fuels, such as kerosene, diesel, and electricity, lead to a wrong choice of energy mix not only in the mountains but also in the plains; and
- lack of technological innovations since choices were made on an *ad hoc* basis (Box 7.2).

Box 7.2: Making the Wrong Choice

The decrease in availability of fuelwood is making itself felt in many parts of the HKH region and is reflected in such things as uprooting of vegetative cover, an increase in the time taken for collection of fuelwood, and increasing use of 'other' biomass fuels. There is no visible impact of technological innovation even though the crisis is being felt. There are three main reasons for this: a) women are responsible for cooking and managing the fuel supply, but are not involved in household decision-making; b) the resource cost of fuelwood is never reflected in making choices for this fuel; and c) the opportunity cost of collecting fuelwood is never realised and thus fuelwood is treated as a 'free' gift of nature.

Source: Rijal 1997a

7.1.3 Lack of a Perspective for Energy Quality and Quantity

Most of the time no distinction is made between the availability of fuelwood and the availability of hydropower. They are considered as freely substitutable for one another under all circumstances, with the choice of which to use based primarily on the (financial) cost. The lack of any perspective related to energy quality and energy quantity has led not only to the wrong choice of energy resources and technologies but also to the scale of energy technologies and institutions.

No initiative is being taken by demand side institutions on the choice of energy mix. Planning for provision of energy is seen as the responsibility of energy institutions and therefore lacks a demand side perspective in most cases. The comparative advantages of energy synergism are not understood. Energy resources and technologies are chosen without properly studying the social and cultural factors that could affect the level and type of energy services demanded. Very little is known in terms of these factors and they do not receive adequate attention when the energy supply infrastructure is designed.

7.1.4 Lack of a Long-term Vision

Development of energy has never been viewed as a means of alleviating poverty and reducing drudgery in mountain communities. It has always been viewed simply as an input for enhancing productivity and income and for diversification of the economy. On the one hand, most of the development policies in the HKH mountains fail to understand the role of energy in reducing human drudgery and generating income to enhance employment, thereby leading to diversification of the mountain economy. On the other hand, the conventional wisdom that the way to provide electricity is by extension of the grid network (Sharma et al. 1997) assumes electricity to be a welfare package. As a result electricity tariffs are always subsidised without considering the high cost of grid extension, and this has seriously hampered the search for alternative options for providing electricity in the mountain areas that might provide sufficient power for productive applications.

7.1.5 Ignorance of Biological and Physical Aspects of Mountain Areas

Ignorance of the specific biological and physical characteristics of the HKH region has led to the application of inappropriate energy technologies and institutional and financing mechanisms. For example, the scattered settlement pattern means there is a low population density, and the mainly subsistence economy means there is a low level of economic activity and a low level of social and physical infrastructure (reduced accessibility to markets and physical and capital resources). Together these result in a low density of energy demand (Rijal 1996a) linked with a concentrated demand for energy at particular times of the day and year. The expansion of transmission lines associated with the prevailing low load factors in the mountain areas reduces the overall load factor of the power supply system – making these investments costly. The emphasis is always on expansion of the supply. The potential economic and social benefits of decentralised renewable energy technologies are not recognised. Neither is the fact that community-based participatory institutions are more sustainable for managing and operating decentralised energy systems in the mountains.

7.1.6 Choice of Technology and Dissemination

A greater interest in the development of renewable energies emerged at the global level after the oil crisis in the 1970s. Mountain people, however, have always relied on renewable energies, mostly in their natural form, although the era of cheap fossil fuels during the 1980s prompted many to shy away from renewable energy development. The situation has worsened with donors viewing technical assistance as a market promotion effort and governments tending to view subsidies as a social obligation, neither party understanding properly the dynamics of technology transfer processes in the context of mountain areas. Renewable energy technologies aimed at resolving the energy crisis in the HKH mountain areas have been demonstrated and disseminated without any standardisation of components and parts, leading to a weak local manufacturing base and limited service capabilities. At the same time, these technologies were not designed to meet multiple user needs at affordable prices. In general, the new technological interventions introduced into mountain areas were only able to fulfill a particular need, in contrast to the traditional technologies that were able to fulfil multiple needs. For example, traditional cooking stoves fulfill cooking, space heating, and drying needs, whereas improved cooking stoves only meet cooking needs (Rijal 1996b). Research and development into renewable energy technologies never received the attention it deserved and no technological innovations occurred. This is particularly unfortunate in the HKH region where there are tremendous resources of renewable energy.

Most of the time energy technologies have been disseminated in the mountains before they have had time to mature, and mountain people have been forced to accept unknown risks. The role of the government was never clear to the consumers or the developers. They were not sure whether the government was trying to minimise their risks or provide mechanisms that offered opportunities for government employees to fulfill their vested interests.

Economic and financial assessments and calculations are needed before making technological choices so that the synergy of sectoral linkage can be optimised and sustainability achieved. The economic costs of alternative energy options have never been considered properly, however, rather a blanket approach to disseminating technology has been followed. Most of the time, government organizations were sceptical of initiatives taken by the private sector, and there was a lack of confidence between the various stakeholders, each of them viewing the other parties with suspicion. Thus there has been no chance for institutional innovation to take place.

7.1.7 Gender, Participation, and Sociocultural Issues

The role of the different stakeholders involved in the development and use of energy is not properly recognised and no emphasis has been given to ensuring the active participation of women in the design and implementation of energy programmes. The energy technologies being promoted do not recognise the sociocultural implications of technology adaptation. It seems, for example, that no priority is given to the specific needs of the users and communities when promoting small-scale decentralised energy systems. Indigenous knowledge and institutions run by local people are not used properly in managing energy systems (Rijal 1997a). There is no mechanism to ensure proper mobilisation of local resources in order to reduce dependency on outside knowledge and resources. The development of energy technologies is based primarily on the needs as perceived by experts and planners instead of as perceived by the local residents - who are the direct beneficiaries. No attention has been given to ensuring that women are included when promoting new and renewable energy technologies in mountain communities, even though they are the people who manage household energy systems.

7.1.8 Institutional Issues

The evolution of energy decision-making as a supply side activity has led to the creation of centralized planning institutions (Rijal 1996). This has resulted in a lack of decentralised institutions for managing the energy sector, so that no institutional capability exists at local level. However, the quantity and quality of energy required for the HKH mountain communities, and the type of energy resources available at local level, favour decentralised renewable energy systems. These require local level decentralised institutions. Demand side agencies (urban and rural development bodies) operating at local level do not see their role in terms of managing the energy sector and believe that this falls under the purview of energy-related institutions such as government owned electricity and forest departments, fuelwood supply depots, and oil depots (Rijal 1997b). The private sector and NGOs do not have any say in the energy decision-making process as the provision of energy is the prime responsibility of governments. Thus rural electrification and renewable energy programmes are dominated by centralized public monopolies.

7.1.9 Cost, Financing, and Investment Issues

The high up-front costs of renewable energy technologies, the existing subsidies on conventional commercial fuels (i.e., petroleum fuels and electricity), and the low purchasing power of mountain consumers make RETs unattractive. Although operating costs may be lower than those of conventional technologies, consumers are unaware of the difference between energy costs and life-cycle costs, so that their choice is based on up-front cost and energy costs.

Most of the time the choice of energy technology is based on a an overall financially 'least cost' approach without taking into consideration the implications for low-income groups and the poorest of the poor (Rijal 1996a). This approach favours non-renewable sources of energy as options for supplying electricity since social and environmental costs are not taken into account.

Bilateral and multilateral donors are biased towards financing centralized energy supplies rather than multiple decentralised energy projects, because of the increased burden imposed by the latter in terms of fund disbursements (Rijal 1997b). This situation is worsened by the fact that national and international financing institutions have conservative lending practices and avoid risks associated with new energy markets. Thus it is difficult for an entrepreneur to acquire venture capital or financing for initial market creation. The credit policies in most of the countries within the HKH region are not sensitive to low-income groups, since financing institutions require some collateral for financing projects. Most of these institutions are guided by the principles of commercial lending, and there is a lack of financing institutions that can cater to the development needs of HKH mountain communities.

7.1.10 Environmental Issues

The production, consumption and distribution of energy — primarily fuelwood, large-scale hydropower and fossil fuels — add to the numerous causes of the overall degradation of environmental conditions in the HKH mountain areas. The main effects are summarised in Box 7.3 and discussed further below.

Deforestation and use of biomass fuels contribute significantly to the environmental problems in the HKH mountains. Deforestation not only results from wood-cutting for burning, however, nomadic agro-pastoralism, conversion of forest lands to

Box 7.3: Environmental Implications of the Production and Use of Energy

Energy Sector	Activity	Effect on the Environment
Fuelwood/ twigs/bushes	Burning	Indoor air pollution and health effects; deforestation; ecological impacts resulting from loss of wildlife habitat; erosion and watershed disturbance; increased flooding; low flows in dry season.
Agricultural and pollution animal waste	Burning as fuel	Loss of organic matter, reduction of soil fertility; local air
Electricity	Large hydro	Land submergence; displacement of people; resource use conflicts; effects on natural aquatic and riverine habitats; local climate change; ecological impacts; erosion and watershed disturbance.
	Transmissio n/ distribution	Displacement of people along right of way; potential radiation impact on humans from high voltage lines.
	Thermal	Sulphur dioxide and nitrogen oxide emissions with human health effects and possible crop damage; increased CO_2 emissions and thus global warming when using coal.
Gas and oil (màinly gas)	Production/ combustion	Water pollution; toxic air emissions; air pollution in cities and towns (lead and CO; respiratory diseases; lead poisoning)
Coal mining	Production	Land disturbance, resettling of residents; dust emissions; acid mine drainage and pollution of streams; destruction of wildlife habitat

Sources: PGOB 1995; PEP 1995; Bansal 1997; Banskota & Sharma 1997; Mengjie 1997; Rijal 1997b permanent pasture and agriculture, commercial logging, and overgrazing all play a role. Inefficient burning of biomass on open fires, combined with inadequate ventilation, represents a serious health hazard – especially to women. The use of agricultural and animal wastes as fuel is also depriving the soil of much-needed organic fertilizer, with a resultant loss in soil fertility and land productivity.

The construction of large reservoirs for irrigation and power generation in hilly areas can have a profound impact on the environment and ecosystem if appropriate mitigation measures are not taken during the planning stages. Large dams, which impound large volumes of water, pose several environmental and ecological problems such as reservoir siltation, deforestation, population displacement, decline in wildlife population, loss of biodiversity, increase in incidence of landslides from steep hill slopes, water-logging and salinity, increase in geological hazards - mainly induced seismicity after the impoundment, and changes in precipitation rates (Sharma et al. 1997)

The mining of coal and petroleum fuels as well as their increasing use in the industrial sector give rise to a number of environmental consequences. For example, mining of coal in Sichuan in China and Balochistan in Pakistan causes land disturbance, resettling of residents, pollution of rivers, and destruction of wildlife habitats, as well as giving rise to sulphur and particle emissions from mining as well as from combustion posing hazards to human health. (Abdullah 1997; Mengjie 1997).

Similarly, the combustion of fossil fuels generates pollutants such as lead, sulphur-oxides, carbon monoxide, and other greenhouse gases that are principal causes of local air pollution (sulphur and particulate matter); regional problems such as acid rain, and global climate change. CO_2 is one of the principal greenhouse gases generated by human activities. The main concerns with regard to global warming in the context of mountain areas are the increasing rate of deforestation and the inefficient burning of biomass fuels. Examples include: i) the increasing use of fossil fuels to generate power in Balochistan in Pakistan and the Sichuan and Yunnan Provinces of China (Abdullah 1997; Mengjie 1997); and ii) coal being employed in the brick industries of Kathmandu in Nepal, Dehradhun in India, and Balochistan and Peshawar in Pakistan (Banskota & Sharma 1997; Bansal 1997; Mengjie 1997).

In most cases commercial fuels are subsidised and no appropriate incentives are available to encourage the use of renewable energy resources. Thus the use of non-renewable fuels will increase even though this is environmentally unsustainable. There is a need to estimate the environmental costs of energy development and use and to internalise them when evaluating the best energy mix to be used in mountain areas. Development of a form of energy may create environmental hazards at any level from production to user, and these different hazards should all be taken into account. For example, solar photovoltaic systems installed in the mountains are free of air pollution but the systems may generate pollution at the production level.

Some energy resources such as micro-hydropower, solar and wind power, and specific biogas options are more environmentally friendly than others such as combustion of fossil and biomass fuels. But increasing forest area and crown density through afforestation and forest enrichment in order to provide fuelwood could have a carbon sink advantage to offset global warming.

7.1.11 Methodological Dilemma of 'How to Value the Environment'

A number of valid environmental concerns has been raised by experts in the context of mountain areas. The most prominent among them are: a) the increasing rate of deforestation; b) indoor air pollution resulting from inefficient burning of biomass fuels which results in significant health hazards, particularly for women and children; c) increasing outdoor air pollution in some urban areas in the mountains as a result amongst others of inefficient burning of biomass, coal, and petroleum fuels in brick kilns and bakeries as well as in the transportation sector; d) decreasing soil fertility and increasing soil erosion as a result of the diversion of agricultural residues and animal dung from the farm to stoves; and e) increasing concern about global warming; although the HKH mountain areas do not contribute significantly to the problem at present they may contribute substantially in the future if developments in the energy sector are left unchecked.

No generally applicable or accepted robust methodology exists for the valuation of environmental resources. In the HKH region at best a mitigating approach is being adopted in project development which is not sufficient to capture the environmental concerns in a holistic manner. Box 7.4 briefly describes a case study highlighting the fact that proper estimation of total benefits and costs may show that large dams do not necessarily ensure a net benefit to the economy. A number of approaches to estimating full costs, including environmental and social costs and benefits have been proposed at various levels of analysis, but the debate still continues. Such approaches include: a) the concept of a 'green' net national product by which GNP is adjusted for depreciation of human-made capital assets and natural capital; b) an Environmentally Adjusted Net Benefit, defined as the difference between the net benefit and the cost of environmental damage; and c) the concept of lower discount rates to introduce a bias towards renewable resources (Rijal 1997c).

7.2 Approach to the Development of Sustainable Energy

Conceptually, energy development in the HKH mountain areas can be considered sustainable if the provision of energy satisfies the services required to fulfill the objective of sustainable human development. Towards this end, indigenous renewable

Box 7.4: Estimating Costs and Benefits: For Whom?

Paranjpye (1988) performed a micro study on the Tehri dam, India, that showed discrepancies in the statistics used in working out the cost/benefit (CB) ratio. For example:

- the 'peaking' was calculated at 87 per cent, as against the Indian Planning Commission Review value of 70 per cent;
- the cost benefit ratio was estimated without considering transmission and distribution losses; and
- the cost of transmission and distribution were not taken into consideration.

Palmer (1982) reviewed the study conducted by Williams on energy accounts for the New Melones Dam in California and noted that net loss of energy may result from dam construction. Critics may argue that the New Melones Dam was an exception, or that William's methodology is debatable, but there is no arguing that energy accounting should be done for a proper calculation of the cost benefit ratio, and that possible cost escalation, delays, and targets not being achieved should be taken into account. Looking at large dams from a strictly economic point of view, there is enough evidence to suggest that they are a bad form of investment.

Sources: Singh 1990; Rijal 1997c.

resources should be exploited in such a way that the social benefits are optimised giving due recognition to the effects and implications of the specific characteristics of mountain areas on the energy sector. There is a need not only to understand the type of energy services required and the environmental implications of exploiting a particular source of energy, but also to understand the concept of sustainable human development and the effects and implications of the specific characteristics of mountain areas on the energy sector (Rijal 1996a). Examination of these issues will lead towards the identification of suitable energy resources in these mountain areas, not only from the point of view of environmental sustainability but also from that of financial sustainability. Institutional sustainability will also be vital to the success of the energy programme.

7.2.1 The Concept of Development of Sustainable Energy

The concept of sustainable development has been brought to the forefront by the Brundtland report (WCED 1987) which emphasised meeting basic needs and conserving environmental resources by incorporating inter-generational equity. The Human Development Report, 1994 (UNDP 1994) introduced the concept of sustainable human development, which suggests incorporation of intra-generational equity with emphasis on the 'universalism of life claims' - meaning 'the right of all human beings to a just opportunity to make use of their potential capabilities'. These concerns stress that development of sustainable energy can only be achieved if the energy is seen both as a means to satisfy basic human needs and as an input to economic transformation, as well being a source of environmental degradation (as suggested in Agenda 21, Chapter 9) (Rijal 1996a; Rijal 1997b). This means that energy is required not only to meet the increasing demand created by promotional activities to support the on-going process of diversification and intensification of agricultural and economic activities and to meet the basic needs of poor people, but also that the available renewable energy resources should be treated as an economic commodity with a potential to enhance the income levels of mountain communities and reduce human drudgery, particularly that of women and children, while ensuring environmental sustainability (i.e., without degrading the environment).

7.2.2 The Specific Characteristics of the HKH Mountain Areas and the Effects on and Implications for the Energy Sector

The extremely slow pace of development of the energy system in the HKH mountains can be attributed to the slow growth rate of economic activities as a result of the prevailing plains biased development paradigm which is unsuitable for the mountain situation. Thus it is important to understand the effects and implications of the specific characteristics of the HKH mountain areas on the energy sector prior to formulating strategies for the development of the energy sector in this area.

The specific characteristics of the mountain areas, inaccessibility, marginality, and fragility, shown in many ICIMOD studies (Rijal 1996a) have many implications for the energy sector (Box 7.5). Inaccessibility induces isolation which means high costs for energy supply systems. This in turn forces local residents to modify their needs to what they have and develop a better understanding of sectoral links (that is, how to maintain the delicate balance between fuel, fodder, and food requirements).

Fragility reflects the vulnerability of energy resources. The low productivity and low resource capability result in dispersed settlements and thus high costs for infrastructural systems for the supply of energy.

Marginality results in the exploitation of available energy resources by people living near them. The rapid process of 'destruction at the margin' is a visible phenomenon resulting from the extensive use of marginal areas by people without easy access to other resources. Furthermore, people residing in the mountains do not have much say in the development process since the cost of not doing anything for the moun-

Box 7.5: The Specific Characteristics of the HKH Mountain Areas and Their Effects on and Implications for the Energy Sector

Specific Characteristics	Primary Attributes	Adaptation Characteristics	Effects on the Energy Sector	Implications for the Energy Sector
Inaccessibility	Isolation; high cost of supply systems; limited access; invisibility of problems	Multiple use of resources and technologies	Interventions failed as a result of sectoral approach	Better understanding of sectoral links, i.e., fuel, fodder, and food chains
Fragility	Wood resource highly vulnerable to rapid deforestation; low productivity & resources; dispersed settlements; prevailing barter system	High community participation; people-oriented problem solving; integrated farming systems	High costs of interventions; higher level of energy input	Augment energy supply; improve efficiency of conversion
Marginality	Limited resources and productivity; minimal consideration of areas/ people; subsistence economy	Exploitation of potential by population of core areas, use of marginal areas by others; dependency; low risk taking capability	Process of destruction at margin slow pace of dissemination	Encourage forest management to provide fodder, fuel and timber Link energy and income generation;
Diversity	Diverse resouyces and approach; large-scale micro-variations in physical/biological attributes	Multiple cropping; diversified up-and and lowland farming systems	Increase in energy inputs, increased dependency on a specific fuel	adop: need-based approach; diversify fuel use
Niche	Small-scale specialisation location and area specific comparative advantages; location specificity of production and consumption	Emphasis on activities that are mostly of an extractive nature like logging and hydroelectricity	Decentralized energy system preferable	Indigenous technical knowledge-base for maintaining forest areas, traditional water wheels

Source : Rijal 1996

tain people does not affect the power equation. Thus the region remains outside the key development negotiations and subsequent energy technology interventions.

Diversity means that the cost of extraction of energy resources in usable form is high, and also that it is not possible to realise economy of scale because of the diverse nature of economic outputs (in terms of quality and quantity). In order to negate the disadvantage associated with economic outputs, particular resources and technologies tend to be used for multiple applications.

The opportunities that exist in the mountains include the huge potential for renewable energy and the existence of indigenous technical knowledge systems used to operate traditional institutions and technologies and to maintain an ecological balance.

7.2.3 Suitability of Energy Resources in the Mountains

The appropriateness of energy resource, technology, and institution needs to be judged not only on the basis of the quality and quantity of energy services required, but also on the physical environment. For example, the quality of energy services required dictates the choice of energy resource and technology (fuelwood, biogas, electricity), whereas the quantity required dictates the scale of energy technology (decentralised, centralized) and type of institution needed (private, public, participatory). These in turn determine the suitability of particular types of financial infrastructure (commercial or development bank, community schemes).

At the same time, the suitability and relevance of a particular form of energy need to be examined not only from the point of view of the energy demand structures and their associated environmental impacts, but also from the point of view of the implications for income redistribution and income from the production of energy. Box 7.6 summarises these concerns and examines the suitability of particular energy resources and technologies in the HKH mountain areas.

As an example, in dry mountain areas, mini-grid systems run by diesel generators provide both light and motive power but have a limited impact on income redistribution. The fuel to operate generators is imported from outside the area. In wet mountain areas, small hydropower development is most relevant for the same purpose, but has a strong impact on income redistribution. Here only the equipment is imported, the actual resource is available locally.

The provision of energy has considerable implications for income redistribution, especially when it becomes available to some and not to others (individual families, selected valleys) and when it is supplied at a subsidised rate, as is especially the case with electricity from the grid which is not only cheaper than subsidised petroleum fuels, such as kerosene and LPG, but is also much more convenient. Another important aspect is income generation from the production of energy (Box 7.7).

The energy required in the HKH mountains is primarily low quality energy, in other words energy to provide heat. Thus renewable energy resources (primarily biomass) will continue to play a dominant role in the region. It is important to realise that biomass can be a renewable fuel if it is exploited and used judiciously. This means that the rate of extraction of biomass for fuel should not exceed the rate of replenishment, so that only a sustainable yield is consumed and the resource is not exploited rampantly.

Box 7.6: Suitability of Energy Resources for the HKH Mountain Areas

Energy Resource	Relevance for mountain areas	Application potential in the mountain areas		Income from Production	Impact on income distribution	Import/Export
		Production	Consumption			
Oil	all	transport	transport	no	no	imports only
Electricity a) from grid	+/- one-third of dry mountains	industry	lighting/ agriculture	limited	Strong	imports
	+/- half of the wet mountains	industry	lighting/ agriculture	limited	Strong	exports
b) Small hydro	strong in wet mountains	cottage	lighting industry	possible	Strong	imported equips.
c) Diesel genset (mini grid)	Strong in dry mountains	cottage	lighting	limited	limited	imports of oil
d) Solar unit	high in dry mountains	no	lighting	possible	if subsidised	import equips.
	high in remote mountains	no	lighting	possible	if subsidised	imported equip.
Natural gas	may be appropriate for urban areas	no	heating/ cooking	limited	limited	imports
LPB	Minor	no	heating/ cooking	no	some	imports
Coal	minor	brick-kiln	heating/ cooking	limited	no	imports
Biomass	major source	cottage	cooking/ heating	cash & non-cash	no	exports
Wind power	possible	water &	lighting	possible	possibly	import equips.
Micro hydel	high industry	cottage	lighting	possible	possible	limited imports
Geothermal	possible	no	tourism/ heating	possible	possible	limited imports
Solar	high industry	cottage	heating/ hot water	possible	possible	limited imports

equip. = equipment

The total quantity of energy services required in the mountains is quite low as a result of the scattered settlement pattern and lack of infrastructural development. This, together with the fact that mountains are extremely scale-sensitive as a result of their fragile nature, makes decentralised energy systems more viable and thus suitable in the mountain context. Small-scale interventions in mountain communities also pose less of a risk than do large-scale interventions, whether road or dam construction or a flow of natural resources to other areas to meet market demands.

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Box 7.7: Mountain Energy Resources: Vehicle for Income Generation

A case in point is the hydropower generated in the northern mountain areas of Pakistan, which could be a major source of revenue for the province or state through the development surcharge. Similarly, introduction of the wheeling charge concept has prompted many entrepreneurs to exploit the available water resources in Himachal Pradesh in India to supply electricity to adjoining states with a high industrial infrastructure. This results in additional income for the Himachal State which can be used to meet the development aspirations of the population residing in the State.

Source: Rijal 1998.

An appropriate choice of institutions will be necessary in order to ensure that decentralised renewable energy systems can become operational in mountain areas; the scale of the institutions is likely to be crucial. Community-based participatory institutions are more suitable for the promotion and development of decentralised renewable energy systems.

Thus the development process in the mountains should be accompanied by energy technology interventions that include, but are not limited to: i) increased availability of renewable energy and energy-technology supply infrastructures; ii) introduction and/or increased use of energy conversion devices to alleviate human drudgery and boost productivity; iii) productivity increase which facilitates off-farm employment; iv) improved efficiency of energy use; v) higher value use of energy forms; and vi) increased use of efficient devices.

7.3 Energy Development Strategies for the Mountains

Given the present pattern of energy use and the associated impact, energy policy in mountain areas should consider three main factors. First, biomass fuels (primarily fuelwood) might still be the dominant source of energy in the foreseeable future in the HKH region. Deforestation could be a serious problem if the present trend continues. This pattern of energy consumption will lead to increased greenhouse gas emission. Second, the demand for fossil fuels is rising at an accelerated rate and this trend needs to be reversed. Third, the development of hydropower is expected to play a major role in the mix of energy consumed because of the large hydropower potential. Hydropower, however, although the cleanest source of energy in terms of pollution (Rijal 1997b), has extensive environmental impacts.

Thus energy development in the HKH mountain areas should involve a four-pronged strategy (Rijal 1997c). First, programmes must be geared towards increasing wood resources on a large scale and to upgrading the quality of biomass fuels to meet cooking and heating needs to such an extent that the time spent by women and children in collection is reduced. Second, energy policies for mountain areas should emphasise decentralised production using new and renewable resources and technologies (via rural electrification or motive power generation). Energy should be used not only to sustain and increase economic activities, but also to reduce or alleviate human drudgery, particularly that of women and children. Third, efficient energy technologies should be promoted so that there is significant improvement in the physical quality of life without any increase, or even with a decrease, in the amount of primary energy used. At the same time these technologies should help to reduce the release of pollutants inside the kitchen and into the environment so that the health hazards to household occupants, particularly women, are reduced significantly. Fourth, large-scale development of hydropower should be initiated so as to generate revenue to alleviate the existing poverty of mountain communities and to develop suitable social and physical infrastructures. Care must be taken, however, not only to internalise the associated environmental costs in these projects, but also to see that such development results in the overall development of the mountain areas.

The following programme level interventions are considered necessary for the sustainable development of the energy sector in the HKH region.

7.3.1 Programme-level Interventions

<u>Augment Fuelwood Supplies and Upgrade the Quality of Biomass Fuels</u>

In the HKH region, the energy supply is needed primarily to meet cooking and heating needs. Since biomass fuels remain the main supplier of energy, overexploitation of forest resources has become a critical source of ecological degradation. The possibilities for substituting fuelwood with commercial fuels in mountain areas are limited. Rapid deforestation, besides causing an acute shortage of fuelwood and fodder, is disrupting the agricultural production process and degrading the environment. Therefore, management and development of forest resources must be considered seriously.

It is possible to increase the supply of fuelwood through properly managed plantations (private, social, and public) and improvements in the efficiency of resource extraction. The following forestry programmes should be considered for implementation.

Social/Community and Agro-Forestry Programme

A programme of social/community and agro-forestry e.g., in which user communities are given control of the forest resource and encouraged to practice integrated agroforestry, needs to be promoted, especially in areas where it is too costly (or the benefits are higher) to keep forests under government control, or where privatisation is not worth attempting.

Private Plantation

Private plantations should be encouraged through supportive activities in the form of a package (including such things as loans and nursery services) in areas where the scarcity of fuelwood is severe and market access for fuelwood and wood products is easier.

Government Forests

Public forests should be managed by governments for two reasons. On the one hand, fuelwood and timber requirements need to be fulfilled. On the other, the forest has to be conserved to protect the environment and biodiversity, to reduce the emission of greenhouse gases, and to reduce the rate of soil erosion. Although overall guidelines for management should be formulated by governments, and overall control should lie with them, government agencies are notoriously incapable of actually managing forests in such a way that the two needs are fulfilled. Thus these needs don't actually provide a reason why governments should manage the forests. Detailed programmes for forest management should be developed taking the following into consideration: i) reforestation must be concentrated on marginal lands and encroached forests in areas where the fuelwood demand is high; ii) management practices to increase productivity of the existing biomass should be promoted; and iii) forest development and management should be taken as part of watershed management.

There is a general tendency for users to shift towards employing high grade energy forms as their living conditions improve. In order to meet the demand for high grade energy, a programme needs to be established to develop technologies to upgrade the quality of biomass fuels. There are several feasible technologies (briquetting, biomass gasification) available in the market that need to be tested under mountain conditions. At the same time, the possibility of developing and producing green energy, for example by extracting oil (Jatropa, "Chiuri" butter) or producing alcohol fuels, should receive priority attention in research and development.

Develop Decentralised New and Renewable Energy Systems

So far it has not been possible to develop decentralised new and renewable energy systems on a sustainable basis to any significant extent. This is mainly because: i) fuelwood and other biomass are available to a large proportion of the mountain population effectively 'free of cost', at the same time these people have limited purchasing power and cannot afford to pay for much if any fuel; ii) the mountain population does not have sufficient financial resources for the initial investment in efficient renewable energy devices; and iii) various other barriers associated with decentralised renewable energy sources and technologies such as inconvenience and conflict with social habits and traditional practices.

Programmes and projects should include the promotion and development of new and renewable energy resources and technologies as an integral part of overall mountain development activities, since meaningful development in the mountain areas cannot be achieved in isolation. At the same time, total infrastructure packages should be developed to include such things as road, water, rural electrification, increased accessibility to markets, and proper linkage between urban and rural areas as well as between the plains and the hills. Decentralised new and renewable energy systems (rural electrification, motive power applications) should be internalised in development projects for roads, drinking water, irrigation, community development, formal and non-formal education programmes, women's development, environmental protection and preservation, and cottage industries. Thus it is essential to formulate appropriate policies to promote the development of decentralised renewable energy systems in the context of the HKH mountain areas.

Improve the Efficiency of Energy Conversion

It is useful energy that determines the extent to which energy needs are fulfilled and the quality of life improved, not just the amount of primary energy available. For example, the efficiency of traditional stoves using biomass fuels is low, on average only about 10 per cent, while the efficiency of those based on commercial energy sources, such as natural gas, can be as high as 70 per cent (World Bank 1993). Improving the efficiency of energy use, therefore, will enable significant improvement in the physical quality of life without any increase being required in the amount of primary energy used. There may even be a decrease in the total primary energy needed. At the same time increasing efficiency will lead to a reduction in the amount of pollutants released into the environment. Also, when a particular energy carrier is used efficiently, or a shift is made towards more efficient energy carriers, then inefficiently used sources will be available for other uses. For example, large-scale distribution of improved biomass stoves in the mountain areas could facilitate the use of agricultural residues as fodder and animal dung as farmyard manure. At the same time, the introduction of energy efficient devices, such as light bulbs, improved cooking stoves, electric cookers, and electric motors, offers the possibility of reducing the overall energy demand. Similarly, improving the efficiency of heating equipment employed in cottage industries, such as furnaces and dryers, and introducing solar and other renewable energy technologies are important elements of a strategy to meet the energy needs of the HKH mountain areas.

Large-scale Development of Hydropower

Large-scale development of hydropower can not only generate revenue for mountain areas but will also minimise the increasing dependence of the region on imported fossil fuels. The hydropower development policies prepared by the governments of the region have emphasised energy production, rather than improving the quality of life of the mountain people. A long-term strategy for the development of hydropower should be developed which gives due emphasis to the people and ecology of the mountains.

Rural Electrification as a Mountain Development Programme

Rural electrification, properly planned and implemented, can be an important component of a comprehensive mountain development programme. The purpose is to meet energy needs at least-cost. For this, alternative electricity supply options must be considered prior to grid extension, and the choice of an appropriate system should be made on the basis of the economic, social, and environmental merits. For example, options for providing electricity from centralized and/or decentralised energy systems must be compared keeping the aspect of affordability in mind, and cost-effective technological options that use energy efficiently and are environmentally friendly must be considered.

7.3.2 Policy and Institutional-level Interventions

The following policy and institutional level interventions are required to create a conducive environment for the programme interventions suggested above, and thus to achieve sustainable development of the energy sector in the mountains.

Policy Aspects

Removing Existing Price Distortions: There is a big difference between the market price and economic price of various energy forms (for example traditional versus renewable energy; renewable energy versus fossil fuels). As long as this distortion in energy prices exists, there will be little scope for renewable energy forms and efficient technologies that are economically cost effective to find their place in the mountains. Pricing policies and regulations should be directed to reducing existing distortions in the pricing of different fuels and in the transaction cost of fuelwood.

Encouraging Entrepreneurs: National and international financing agencies are hesitant to invest in new energy markets because of their attitude of risk aversion. Innovative entrepreneurs are thus not able to acquire venture capital and financing for initial market creation. Existing credit policies do not address or cater for low-income groups and the landless since they require collateral for financing. The design of appropriate credit policies with proper load development strategies will encourage otherwise diffident entrepreneurs to take part in the development of renewable energy technologies. The high up-front costs of renewable energy technologies, together with the prevailing subsidies on commercial fuels, also hinder innovations in renewable energy resources and technologies. The role of financing institutions should be to lessen the burden of the up-front capital costs of renewable energy technologies to users by designing suitable financing schemes.

Technology Transfer and More Efficient Fuel Use: Technology transfer and economically justified fuel switching do not occur overnight. Adoption of environmental taxes and regulations as an incentive for energy consumers to adopt cleaner fuels and pollutant abatement technologies is an effective means of promoting the transfer of efficient technologies for production and consumption. There is a potential for large efficiency gains using technologies readily available in international markets. The provision of tax incentives for the import of efficient technologies, and imposition of higher tax rates for inefficient technologies, should be considered.

Information Dissemination: Information on technological options and the availability of such things as efficient cooking stoves, light bulbs, motors, and kerosene stoves must be disseminated so that energy companies and consumers are kept aware of recent developments. In the long run, the dissemination of such knowledge will promote energy efficiency, and information dissemination should be a government responsibility.

Standards and Codes: The introduction of standards and codes, such as air pollution standards, building codes, and minimum levels of efficiency, is an appropriate tool for promoting energy efficiency. However, care must be taken when introducing standards and codes. The provision of economic incentives to achieve goals of efficiency should be preferred to attempting legislation of behaviour without changing the underlying structure of private incentives.

Research and Development: In the context of the HKH mountain areas, it is clear that a greater emphasis will have to be placed on research and development (R&D) of renewable energy forms if they are to make a meaningful contribution to the existing energy systems. The overall thrust of R&D should be on developing low-cost, efficient technologies suited to local conditions. Efforts should be made to develop mountain region specific renewable energy technologies.

Institutional Aspects

The evolution of energy decision-making as a supply-side activity has led to the formulation of centralized energy planning institutions, and now there is no planning capability at the local level. At the same time, there is a lack of awareness about energy among demand-side agencies, especially among development bodies operating at the local level. The voices of the limited number of specialised agencies for renewable energy development are marginalised. The private sector and NGOs have little say in the energy decision-making process. It is absolutely necessary to remove these barriers in order to promote the development of decentralised renewable energy and efficient technologies.

Social/community and agroforestry programmes should be developed to encourage active participation of communities in forest management and other activities to meet their basic energy needs. A mechanism has to be developed by which villagers are encouraged to manage government-owned forest using a community-based approach. To some extent this is already in progress in some countries in the region. The design of agro-forestry programmes should take into account the need to encourage participation of the population in the planting of trees around homesteads and in farmers' fields by including necessary incentives and support to the farmers. Similarly programmes related to decentralised renewable energy systems and efficient energy technologies must ensure the participation of local beneficiaries to enhance the sustainability of the programmes.

An independent and autonomous apex body solely responsible for all aspects of decentralised new and renewable energy development programmes is needed. Such an institution is a prerequisite for the effective development, promotion, and dissemination of new and renewable energy technologies in a well coordinated and sustainable manner. The primary responsibility of this institution would be to establish proper and meaningful linkages between government research institutions, technology manufacturers, suppliers/promoters, and INGOs/donor agencies/financing institutions. Other responsibilities might include standardisation of equipment and quality control, safeguarding the interests and rights of the consumers/users, devising effective and appropriate incentive mechanisms, channelling subsidies and other financial incentives, and coordination between the various actors involved in promoting decentralised new and renewable energy technologies.

Womens' Participation in Energy Programmes

Gathering of fuelwood is time consuming and exhausting work that is traditionally the responsibility of women – who are thus diverted from other activities, such as education and farming that could eventually improve their productivity and living conditions. Similarly, the combustion of biomass, which is the main source of energy for cooking and heating in rural areas, produces pollutant gases that are hazardous to human health, and these affect women more because they are the ones mostly involved in cooking. At the same time, new technologies will only be used if they are acceptable to the people actually using them mainly women. Thus women must be involved in programmes on forest development and utilisation, development of efficient end-use energy devices, and development of decentralised renewable energy systems.

Human Resource Development

Forest development and management programmes have complex organizational and technical requirements. It is essential to arrange staff training so that those involved can design and implement forestry policies and programmes. Successful implementation of such programmes can be accomplished only through extensive training programmes. Similarly, training should be provided on the application of energy technologies, as well as on the need to change energy use behaviour and practices in order to achieve efficient use. At the same time, the decentralised electric power systems should be operated by efficient skilled and/or semi-skilled local people and professionals rather than outsiders, and an appropriate training package needs to be developed for this.

Lack of appropriate data on the local manufacturing capability for decentralised renewable energy technologies and ignorance of the technology transfer process hinder the enhancement of technological capability. To counter this, it is essential to provide appropriate incentives for manufacturers and NGOs by initiating programmes for human resource development.

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Solar photovoltaic lamp installed to provide light for the operation of a communication facility, Kumaun hills, India

Pedal-operated de-husker *(Dhiki)*, Arunachal Pradesh, India

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Nepali women carrying fuelwood for cooking fuel

Latrine attached dome-type biogas plant, Panchkhal, Kabhrepalanchok, Nepal

Solar lamp being used to supply power to operate a television set, Kumaun, India

Annex A

Methodological Guidelines for the Preparation of an Energy Database

by
Kamal Rijal

A.1 Introduction

Given the rapidly declining costs of computing power and data storage space, the volume of data that can be compiled in a database employing computers is limited only by the capacity to collect it and the nature and sources of the information. The capacity to collect data and sources of information is determined by the resources available. Sources of information can be classified as primary and secondary. The collection of primary information requires a huge amount of resources, whereas the collection of secondary information requires less time and money.

Designing an appropriate database for energy requires that certain steps be followed. The steps involved are described in the following.

A.2 Basic Design Consideration

The following design considerations offer a set of useful references to highlight the central issues related to the energy database.

Quantifiability: Most aspects of the energy system are quantifiable, although the degree of quantification may vary from one data item to another. A good example is that of fuelwood supplies to villages. These can be quantified by volume (bundle, head-load, or similar measures) or weight (kg or tonnes). Quantification by weight would clearly be more useful for planning purposes as these values can be converted into heat values if the moisture content and fuel type (wood species) are known.

Reliability: The reliability of information depends on factors such as the data source, method of data collection and enumeration, and accuracy of the data. These factors can only be improved through experience gained over a period of time. It is desirable that an appropriate system of data validation should be built into the design of the database. For example the total estimated supplies of kerosene may not tally with the total estimated demand when supply and demand data are drawn from different sources. If this is so, then either one of the two estimates is incorrect, or data is missing. The two estimates can be reconciled if a data validation procedure is incorporated into the database.

Comparability: The data must be comparable across different geographical areas and time periods. In the absence of geographical comparability, it will not be possible to make useful aggregations. For example, aggregation of information from several districts and/or states into regional information will only be possible if all data are classified according to the same definitions and entered into the database in the same form. For this it is necessary to develop a standardised format for the energy database.

Ability to Collect and Update: The operational feasibility of a database depends on the extent to which the data specified can actually be collected and updated on a regular basis. For this, information should be considered that can be provided by an appropriate institution that already performs collection and regular updating. For example, the information available from public utilities related to electricity demand forecasts might be used.

A.3 Establishing Boundaries

The boundaries of an energy database related to the HKH area may be different from the physical boundaries of the energy system itself. The physical boundaries of the energy system are determined by energy flows. For example, oil products and grid electricity imported into the HKH area are extracted and processed outside the physical boundaries of the region. Their point of origin should not be considered when determining the physical boundaries of the HKH energy system. They should be included in the form of 'imports', i.e., as originating from outside the boundary. A more practical way to determine the boundaries of an energy database in the context of the HKH area would be to estimate or compile the energy requirement data and then to assess to what extent these energy requirements could be met by the energy supplies available within the physical boundaries of the area.

A.4 Elements of the Energy Database

Energy databases should be categorised into different data modules based on the energy flows from resources to end-use applications and further classified on the basis of the institutional set-up for energy planning. In the context of the HKH area, state-level information together with agro-climatic classification may be appropriate, but this classification depends primarily on the availability of such information. Data modules classified on the basis of energy flow, however, are quite distinct from one another. The contents and boundaries of these modules are described briefly below (Codoni et al. 1985).

Energy Supply Resources Data: Data on energy resources are required to assess their availability over a period. In the case of non-renewable energy sources, availability is indicated not only by the physical reserves of the resource but also by the economics of its extraction from various sites. The availability of renewable energy sources, such as hydropower, solar, and wind is perpetual, their exploitation is determined by the economics of production costs. The availability of certain renewable resources such as biomass is determined by the perspective of sustainability, which is generally defined in terms of production to regeneration ratios, taking into consideration the need to balance the amount of resource extracted against its natural replenishment rate. The main categories in the module are as follow.

a. Primary Energy resources
   a.1 Traditional energy Forms
   - Fuelwood
   - Agricultural Residues
   - Animal Dung
   - Industrial Waste
   - Other Biomass
   - Animal Labour
   - Human Labour

   a.2 Non-conventional Energy Forms
   - Solar
   - Wind
   - Small Hydro
   - Geothermal

   a.3 Conventional Energy Forms
   - Coal
   - Crude Oil
   - Natural Gas

b. Secondary Energy Forms

b.1 Non-conventional Energy Forms

- Gaseous Fuels
  - Biogas
  - Producer Gas
  - Others, if any
- Liquid Fuels
  - Ethanol
  - Methanol
  - Others, if any
- Solid Fuels
  - Charcoal
  - Briquettes
  - Bagasse
  - Others, if any

b.2 Conventional Energy Forms

- Diesel
- Kerosene
- Motor Spirit and Aviation Turbine Fuel
- Furnace Oil
- Other Oil Products

c. Final Energy Forms

c.1 Non-conventional Energy Forms

- Decentralised Electricity
  - Solar Photovoltaic Systems
  - Wind Generators
  - Others, if any
- Grid-fed Electricity Generation
  - Wind Generators
  - Bagasse-based generation

c.2 Conventional Energy Forms

- Grid Electricity
  - Thermal
  - Hydropower
  - Nuclear
  - Coal
  - Others, if any

The data items needed for each category are:

- theoretical reserves or yield,
- exploitable reserves or yield,
- location of reserves,

- areas/regions of shortfall/surplus,
- quality of the resource (by type, grade),
- average energy content per unit of the resource,
- main end-uses of the resource (including non-energy end-uses),
- price per unit (by different markets, indicating subsidies, if any),
- non-price barter arrangements, if any, and
- principal data sources for the items mentioned above.

Energy Technology Data: Energy technologies cover a wide range as all the steps in the energy chain from production to the point of end use employ technologies. Technology data should include technical specifications, life-cycle durations, performance factors, fuel consumption, reliability, cost, source of origin, share of local components, and other factors. It is advisable to maintain technology data in a separate module for reasons including: a) the same resource can be exploited using a variety of technologies to produce the same useful energy or a different form of useful energy; and b) technological characteristics change over time depending on new innovations and adaptations as well as R & D efforts, and thus technology data require frequent updating.

Broadly speaking, energy technologies can be classified as: i) process technologies that convert primary energy into secondary energy forms; ii) conversion technologies that convert primary/secondary energy into final energy forms; and iii) end-use devices or demand devices that convert primary/secondary/final energy into useful energy in terms of heat, power, or illumination. These technologies can be further classified, but the list below should be taken as indicative only, as technologies may vary depending on the locations.

a. Process Technologies
   - Charcoal Kilns
   - Biogas Digesters
   - Micro-, Mini-, and Small Hydro Turbines
   - Briquetting Technologies
   - Internal Combustion Engines
   - Transmission and Distribution Systems
   - Solar Air/Water Heating Systems
   - Wind Turbines and Others, if any

b. Conversion Technologies
   - Wind Generators
   - Hydro Generators
   - Solar Photovoltaic Systems
   - Diesel Generators
   - Others, if any

c. End-use Devices (Demand Devices)

c.1 Cooking
- Traditional Cooking Stoves
- Improved cooking stoves
- Kerosene Stoves
- Hot Plates
- Biogas Burners
- Solar Cookers
- LPG Burners
- Others, if any

c.2 Space Conditioning
- Air Conditioners
- Fans and Blowers
- Kerosene Room Heaters
- Electric Room Heaters
- Others, if any
- Other, if any will cover

c.3 Lighting
- Traditional Lamps
- Lanterns
- Biogas Lamps
- LPG Lamps
- Incandescent Bulbs
- Fluorescent Tubes
- Energy Efficient Lamps
- Others, if any

c.4 Process heat
- Electric Water Heating Systems
- Solar Water Heating Systems
- Boilers employing different fuels
- Others, if any

c.5 Heating
- Furnaces employing different fuels
- Others, if any

c.6 Electrical appliances

c.7 Motive power
- Tractors
- Power Tillers
- Irrigation Pumps
- Car/Jeeps/Busses/Trucks
- Aeroplanes/Jets
- Railways
- Trolleys/Trams

- Ropeways
- Traditional Ploughs
- Bullock Carts
- Porters
- Others, if any

The data items needed for each category are:

- Technical Specifications
- Capacity and Rated Performance
- Energy, Material, and Labour Input
- Energy and Material Output
- Quality of Energy
- Efficiency
- Life
- Financial Cost Parameters
- Capital Costs
- Fixed O & M
- Variable O & M Costs
- Cost of Raw Materials
- Cost of Energy Input

(Note: 1. All costs should be classified into materials and labour and local and foreign;
2. Level of subsidy and type of subsidy should be indicated)

Status of technology advancement for each technology needs to be examined so that applicability and replicability of a particular technology can be assessed.

- Commercial Feasibility Status
- Research and Development
- Demonstration and Dissemination
- Commercially Viable
- Technological Maturity
- Obsolete
- Number of Existing Installations
- Installed Numbers
- Numbers in Operation
- Qualitative data on reasons for performance shortcomings

Energy Demand Data: Energy demand data provide the basis for assessment of resource supply and technology evaluation. Since energy demand is a reflection of end-use activities, the energy demand module will have the largest number of interconnections with data in other sectors of the economy. The level of increase in an end-use activity is not the sole determinant of demand and data on many other factors (like energy prices, supply scarcities, income levels, and technology efficiency) will also be required to develop reliable energy demand estimates. The main use of the data is to estimate the volume and pattern of energy demand in the economic sector and to provide a basis for projections of future energy demand. The broad categories of demand sectors with energy consuming end-use activities are listed below.

a. Household Sector Energy Demand
- Rural
- Urban

For each of the above sub-sectors quantify the following.
- Useful energy consumption for
  - Cooking
  - Lighting
  - Water Heating
  - Space heating/Cooling
  - Motive power
  - Others, if any
- Appliance Ownership
  - Radio, TV, Cassette Recorder
  - Electric Iron
  - Other devices should cover best
- Income level
- Family Size

(Note : Identify appropriate socioeconomic parameters for each sub-sector that can be employed to predict useful energy demand.)

b. Industrial Sector Energy Demand
- Cottage Industries
  - Agro-based
  - Forest-based
  - Mineral-based
  - Service-oriented
  - Weaving/Carpets, etc
  - Others, if any
- Modern Industries
  - Food, Beverage and Tobacco
  - Textiles and Leather
  - Chemical Engineering

- Mechanical Engineering
- Electrical Engineering

For each of the above sub-sectors quantify the following.

- Useful energy consumption for
  - Process heat
  - Motive power
  - Heating
  - Lighting
  - Space conditioning
  - Others, if any
- Production Process
  - Type of machinery (mechanical/electrical/manual)
  - Number of labourers

(Note : Identify appropriate output parameters for each sub-sector that can be employed to predict useful energy demand)

c. Transport Sector Energy Demand

- Rural Transportation
- Other Transportation

For each of the above sub-sectors quantify the following.

- Useful energy consumption for - Goods and Passengers
  - Rail Transport
  - Ropeways
  - Airways
  - Trolleys
  - Porters
  - Bullock Carts
  - Others, if any

(Note : Identify appropriate parameters for each sub-sector that can be employed to predict useful energy demand)

d. Commercial/Institutional Energy Demand

- Rural
- Urban
- Commercial Activities
  - Essential Retail
  - Non-essential Retail

- Restaurants
- Hotels and Lodges
- Private Institutions
- Others
- Institutional
  - Hospitals and Health Posts
  - Public Institutions
  - Others

For each of the above sub-sectors quantify the following.

- Useful energy consumption for
  - Cooking
  - Lighting
  - Water Heating
  - Space heating/Cooling
  - Motive power
  - Others, if any
- Appliance Ownership
  - Radio, TV, Cassette Recorder
  - Rice cookers
  - Electric iron and rice cookers if needed
  - Other devices

(Note : Identify appropriate parameters for each sub-sector that can be employed to predict useful energy demand.)

e. Agricultural Sector Energy Demand

- Cereal Crops
- Cash Crops
- Irrigated Land
- Non-irrigated land

For each of the above sub-sectors quantify the following.

- Useful energy consumption for
  - Land Preparation
  - Tilling
  - Ploughing
  - Sowing
  - Crop Production and Processing
  - Irrigation
  - Harvesting
  - Threshing
  - Post-harvest Activities

- Application of fertilizers, pesticides, insecticides, etc
- Crop Yield and Residue Production
  - Crop production by crops
  - Yield per unit of land area
  - Ratio of crop to residue production
- Degree of Mechanisation
  - Number of tractors, tillers, and other mechanical equipment
  - Number and types of irrigation pumpsets (electric, diesel)
  - Contribution of animal power
  - Contribution of human labour

(Note : Identify appropriate parameters for each sub-sector that can be employed to predict useful energy demand.)

Economic Data: Economic data are intended to provide a set of indicators of development. Besides this, it should also include data on the economic and financial prices of primary, secondary and final energy based on quality. The broad categories are as follow.

a. Macro-economic data including the following.
   - Aggregate, sectoral, and sub-sectoral economic output (GDP)
   - Rural and urban per capita income
   - Aggregate and average household income
   - Aggregate and average household expenditure (clothing, energy, food, etc)
   - Summary of ongoing development projects
   - Summary of capital investment (government, public, private sector)
   - Aggregate volume of loans by institutions (banks, rural credit societies, others)
   - Ratio of rural inflation rate to national inflation rate
   - Any other relevant information

b. Economic and Financial Energy Prices
   - Prices of conventional energy supplies sold in rural and urban markets
   - Prices of traditional energy supplies sold in rural and urban markets
   - Nature and extent of pricing subsidies
   - Energy quota and rations
   - Fiscal and financial incentives for private sector investment
   - Any other relevant information

Social Data: Social sector data items are needed to provide a set of indicators for social development. Broadly these include the following.

- Demographic Indicators
  - Population size
  - Population growth rate
  - Labour force
  - Population density
  - Population of tribes and other isolated groups
- Human Deprivation Indicators
  - Population in absolute poverty
  - Population without access to safe drinking water
  - Population without access to health services
  - Population without access to minimum nutrition
  - Number and percentage of malnourished children
  - Infant mortality rate
  - Number and percentage of illiterate adults
  - Number and percentage of illiterate females
  - Number and percentage of children not in primary school
  - Number and percentage of unemployed adults
- Indicators of Social Services/Infrastructure Support Provided (per '000 population)
  - Number of Schools
  - Number of Clinics
  - Number of Doctors and Paramedicals
  - Number of Post Offices
  - Number of Telephones
  - Number of Automobiles
  - Kilometres of Road Length
- Indicators of Rural-Urban Disparities
  - Rural population as percentage of total population
  - Rural-urban migration rate
  - Population with access to health services
  - Population with access to safe water
- Energy Consumer Profile
  - Population with access to grid electricity
  - Population with access to decentralised electricity
  - Energy source preferences
  - Energy technology preferences

Environmental Data: Environmental data items are needed to provide environmental status indicators. Broadly these include the following.

- Climate (Hills, Mountains, Terai)
  - Mean Temperature (yearly, by season)
  - Temperature Range (yearly, by season)

  - Precipitation
  - Humidity
- Deforestation
  - Overall forest loss and annual depletion rate
  - Primary forest cover (with some classification based on crown cover)
  - Area of shrub land
  - Others, if any
- Land Quality
  - Mineral content
  - Toxic chemical content
  - Organic matter content
  - Frequency of landslides
  - Frequency of floods
  - Frequency of droughts
- Air quality
  - Sulphur oxides
  - Nitrogen oxides
  - Carbon dioxide
  - Carbon monoxides
  - Particulate matter
  - Organic compounds
  - Others, if any
- Water Quality
  - Suspended solids
  - Dissolved solids
  - Organic compounds
  - Salinity
  - Alkalinity
  - Turbidity
- Human Health
  - Incidence of airborne diseases
  - Incidence of waterborne diseases
  - Indoor air quality
  - Noise level

<u>*Other Relevant Data*</u>: Those data items not covered in the above data modules but important for the energy sector fall under this category. For example, information on rural electrification is important from the perspective of the energy sector. The categories are indicated broadly below.

- Rural Electrification
  - No. of villages electrified/unelectrified
  - No. of households electrified/unelectrified

- Level of household saturation (ratio of village electrification to household electrification)
- Average electricity consumption per capita

A.5 Collecting the Data

Development of an energy database requires that data be collected from various sources. There are a number of ways to collect data. These can be broadly classified as: i) primary data collection; and ii) secondary data collection methods. Secondary data sources typically consist of the following types of organization.

- National/State Statistical Agencies/Bureaus
- National/State/Provincial Planning Bodies
- Sectoral Ministries/Departments

(Forestry/Agriculture/Industry/Environment/Others)

- National/State/Provincial Electric Utilities
- Ministries/Departments/Specialised Agencies for New and Renewable energy

Development

- Central Bank/Development Finance Institutions/Rural Development Banks/Commercial Banks/Rural Credit Organizations
- Government Research Establishments/Private and Autonomous Research

Institutions/ Regional/International Research Institutions

- National and Public Libraries
- Universities
- Private Sector Energy Equipment Vendors
- National and International NGOs
- Regional/International Multilateral Development Banks
- Bilateral Development Assistance Agencies.

It is important to realise that for many types of data there may be more than one source. In general, it would be prudent to restrict the number of secondary data sources, especially for the same data items. However, for certain types of data having more than a single source could be advantageous as it enables cross-checking and validation. There can be no strict guidelines on the number of secondary data sources, nor for the actual process of collecting secondary data. These should be decided by the experts themselves based on the human resource capability and funds available. It is preferable that all data collection activities should at least conform to two basic requirements: regularity of access and consistency in types of data collected.

A.6 Energy Terminology

The energy terminology currently in use can be quite confusing because of multiple definitions of the same resource, technology, process, or demand. Table A.1 provides an illustration of energy resource classification using four different commonly employed criteria, namely reproductability, familiarity, monetisation, and settlement pattern.

Table A.1 : An Illustrative Example of Energy Terminology Using Different Classifications

Resources/Technologies	Familiarity		Non-	Reproducibity		Monetisation		Settlement Pattern	
	Conventional	Traditional	Conventional	Renewable	Non-renewable	Commercial	Non-Commercial	Rural	Urban/ Modern
Large-scale Hydropower	x			x		x			
Small-scale Hydropower		x	x	x		x		x	
Fuelwood		x	x	x		x	x	x	
Agric. Residue		x	x	x			x	x	
Animal Dung		x	x	x		x	x	x	
Animal Labour		x		x		x			
Coal, Oil and Gas	x				x	x			x
Solar Thermal			x	x		x		x	x
Solar Photovoltaic			x	x		x		x	
Wind			x	x		x		x	
Biogas			x	x		x		x	
Biomass Gasifiers			x	x		x		x	
Improved Stoves			x	x		x		x	x
LPG Burners	x				x	x			x

Agric. = Agricultural
Source: Modified and adopted from Ramani et al. 1995

Many resources or technologies fit into more than one classification and can thus have more than one definition depending on the situation in which they are used. In some cases, the production technology or process determines the classification rather than the nature of the resource. Fuelwood is a good example of possible multiple definitions; it can be defined as 'traditional' because of historic familiarity with it as a fuel source, 'renewable' because of its reproductive nature, 'rural energy' because of its prevalence in rural settlements, and 'non-commercial' because it is normally not traded in a market. But none of these definitions can be followed rigidly under all circumstances. For example, if advanced technologies such as a wood gasifiers are used, fuelwood can be a 'non-conventional' fuel source; in urban markets where it has a monetary price it is a 'commercial' resource; and fuelwood can be a 'non-renewable' resource if it is extracted at a level greater than the sustainable supply. Energy technologies can also be classified in number of ways such as rural, modern, and alternative energy technologies.

The use of different terminology for energy demands can also be confusing. The different types of classification are summarised below.

In general, classification of energy demands based on the physical process is more accepted by energy planners than classification by socioeconomic process. The main advantage of the physical process classification is that it provides a set of coherent connecting links between energy resources and energy end uses which is

Classification by Physical Process

Primary Energy Demand:	The amount of energy required in its natural form prior to transformation into any other form (e.g., fuelwood, agricultural residues, animal dung, solar energy, wind, crude oil, natural gas, coal).
Secondary Energy Demand:	The amount of energy required after transformation from its natural state to a higher form of energy (e.g., charcoal, producer gas, biogas, petrol, diesel, LPG, kerosene, not water from solar water heaters.
Final Energy Demand:	The amount of energy required just prior to its utilisation in an end-use device. The final energy demand excludes all energy lost in the transformation of primary to secondary energy, energy used within the transformation industries, and energy lost in the distribution process.
Useful Energy Demand:	The amount of energy required in the form of heat, light, or work and actually made available to the final user of the energy (industry, transport, household, etc.) after transformation in an end-use device.

Classification by Socioeconomic Process

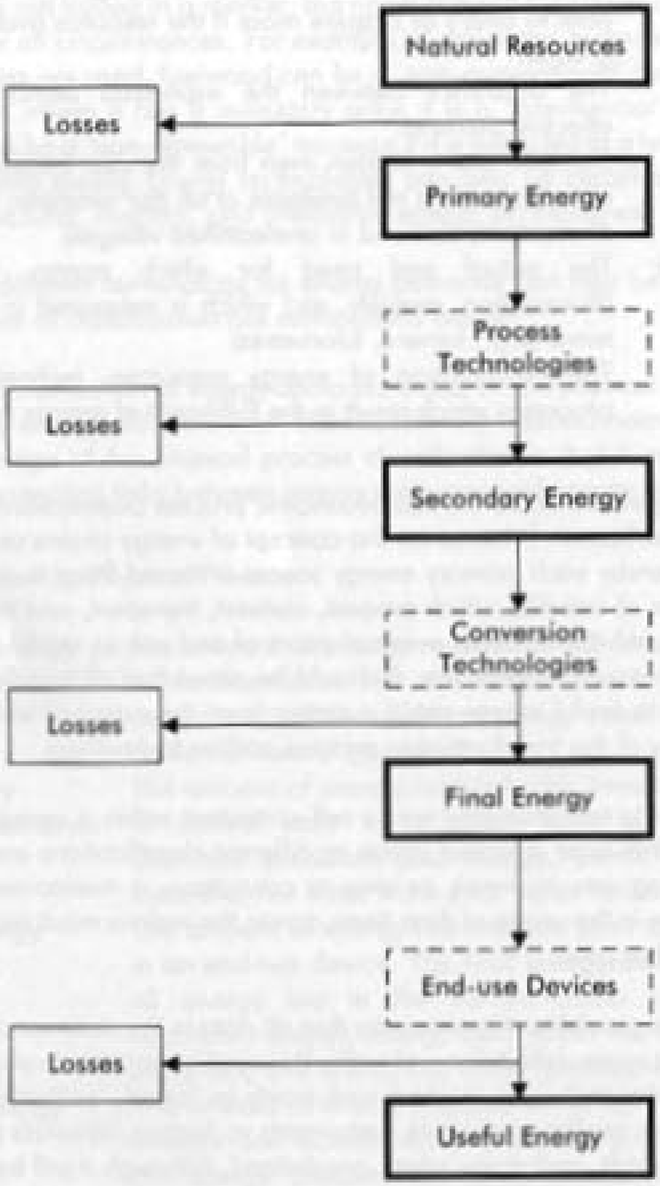
Expressed Demand:	Demand that is expressed in relation to energy supply availability and the user's purchasing power or physical capacity to acquire it.
Effective or Satisfied Demand:	Demand that is actually fulfilled (energy consumed) according to energy supply availability, even though the user may be able to afford or acquire more if the resource availability were greater.
Unsatisfied Demand:	The difference between the expressed demand and the effective demand.
Suppressed Demand:	Demand that is hidden even from the user because a certain energy source is not available at all (for example, the absence of electricity demand in unelectrified villages).
Energy Need:	The actual end need for which energy is required (illumination, mobility, etc) which is measured in non-energy terms (e.g., lumens, kilometres)
Energy Service:	The combination of energy resources, technologies, and processes which result in the fulfilment of energy needs.

not so readily apparent under the socioeconomic process classification. The physical process classification is based on the concept of energy chains as depicted in Figure A.1, whereby each primary energy source is traced from its original state through a series of activities which process, convert, transport, and transform the energy source until it reaches its eventual point of end use as useful energy after passing through an end-use device. It should be noted that all transformations of primary energy to useful energy entail a certain loss, the extent of which depends on the efficiency of the transformation process and/or technology.

Each set of energy terminologies seems self-consistent within a certain classification, but difficulties arise in actual usage as different classifications are often used in an overlapping way. However, as long as consistency is maintained within the energy database in the usage of data items across the various modules and layers, there is no need to panic.

For genuine comparability, it is necessary that all data in the data set are classified according to the same definitions and units. This applies not only to physical quantities, it also applies to the way in which such words as 'forest', 'settlement', rural vs. urban, cottage vs. modern industries, restaurants vs. lodges, absolute poverty, hills vs. mountains, roads, and many others are defined. Although it will be almost impossible to standardise these in a data set drawn from a wide variety of sources, it is necessary to be aware as far as possible of the definitions used in compiling the original sources, and to bear any differences in mind when making overall comparisons.

Figure 1: The Energy Chain



A.7 Energy Measurement and Conversion Units

Energy is defined as the capacity for doing work producing heat. It can be regarded as 'stored work'. Energy can manifest itself in many forms such as heat, light, motive force, and chemical change induced by or resulting in electricity.

Energy is not needed as a physical commodity but in specific forms and qualities which are substitutable. It is necessary to quantify the energy content of various resources by some common unit of measurement when preparing a database for accounting, aggregation, comparison, and/or evaluation purposes. Primary energy can be physically quantified in different ways depending on the type of energy resource as indicated below.

- mass (tonnes of solid fuels such as fuelwood, coal)
- volume (cubic metres of biogas and LPG, and litres of petroleum fuels)
- rate of work (horsepower, Newton)
- velocity (km per hour of wind speed)

Some energy resources require a combination of more than one of the above measures, e.g., the water head for hydropower is a combination of volume and velocity or pressure head. Many traditional energies are measured in non-standard units, such as bundles and headloads, and these must first be converted into standard physical units before further conversion into an energy measure. Converting physical quantities of various resources into a common unit of energy requires appropriate conversion factors such as those shown in Tables A.2, A.3, and A.4.

It should be remembered that no energy resource (or commodity) provides an entirely homogeneous heat value or common unit of measure. The same physical quantities of different types of fuelwood or grades of crude oil often result in different heat values as a result of factors such as density and moisture content. Widely-used measurement units, such as calorific value, can be distinguished as gross calorific value and net calorific value. The difference between the two is the amount of latent heat absorbed during the evaporation of the moisture present in the fuel at the time of combustion, whether present before the combustion took place or produced during the chemical process of combustion.

It is more difficult to measure the energy content of animate energy (including human energy) both conceptually and empirically, but animate energy is the main provider of motive power in HKH areas. There are varying views as to whether animate energy is a factor of production that is substitutable by energy, or a form of energy that is substitutable by other forms of energy. Although the majority view appears to be against treating animate energy as an energy source, there is a need to have some broad estimate of what demand is being met by human and animate

Table A.2: Basic Energy Conversions

Unit	Gigajoules (GJ)	Tonnes of Coal Equivalent (tonnes)	Tonnes of Coal Equivalent (tonnes)
Tonnes of coal equivalent	29.307600	1.000000	0.680272
Tonnes of oil equivalent	43.082200	1.470000	1.000000

Sources : ADB 1992; WECS 1994; PEP 1995

Table A.3: Energy Content of Traditional Fuels

	physical Unit	GJ	tce	toe	Other
- Fuelwood	Ton	16.7	0.57	0.39	1.43 m3
	cu.m.	11.7	0.4	0.27	700 kg
Charcoal	Ton	28.9	0.99	0.67	2.86 m3
	cu.m.	10.1	0.35	0.23	350 kg
- Animal Dung *	Ton	10.9	0.37	0.25	-
- Biogas	'000 cu.m.	24.2	0.83	0.56	-
- Agric. Waste	Ton	12.6	0.43	0.29	-

Some texts use toe = 10,000,000 kcal, or tce = 0.7 toe
Agric. = agricultural
Sources : ADB 1992; WECS 1994; PEP 1995

energy, so that the energy needed to replace or minimise human drudgery by provision of alternative sources of energy can be estimated. It is not possible to provide any uniform conversion factors for animate energy, but some methods described in the literature are provided for illustration.

It is estimated that an adult male working eight hours per day would produce an average energy equivalent of 80 W. The energy equivalent of an adult male working for 1-2 hours without any mechanical aids can be calculated using the following formula (Ramani et al. 1995):

$$P = 0.53 - \log t$$

where, t = time in minutes and
P = energy in kW

Thus, in the first minute, the energy equivalent of human labour is 0.392kW and, after 100 minutes, it decreases to 0.203kW.

Table A.4: Energy Content of Commercial Fuels

	Natural Unit	GJ	tce	toe	Other
- Diesel	k litre	37.9	1.29	0.88	0.826 ton
	ton	46	1.57	1.07	1210 l
- LDO	K litre	39.3	1.34	0.91	0.853 ton
	ton	46	1.57	1.07	1172 l
- Petrol	k litre	33.4	1.14	0.78	0.709 ton
	ton	47.2	1.61	1.1	1411 l
- Kerosene	k litre	36.3	1.24	0.84	0.778 ton
	ton	46.6	1.59	1.08	1285 l
- Av. Tur	k litre	36.3	1.23	0.84	0.776 ton
	ton	46.6	1.59	1.08	1288 l
- F. Oil	k litre	41.3	1.41	0.96	0.934 ton
	ton	44.3	1.51	1.03	1071 l
- LPG	ton	49.2	1.68	1.14	-
- Coal	ton	25.2	0.86	0.59	-
- Electricity	MWh	3.6	0.12286	-	
	ton	46.6	1.57	1.07	1210
Natural Gas	$1000m^3$	36	1.56	1.09	

LDO = light diesel oil Av. Tur. = ??

* dry basis, one tonnedung yields 190 m^3 biogas at 15 °C.

* Some texts use toe = 10,000,000 kcal, or tce = 0.7 toe

Sources: ADB 1992; WECS 1994; PEP 1995

The pulling force of draught animal labour can be estimated in the following manner:

for a bull :	P	=	1.1 - 2.0 M
for a horse :	P	=	1.4 - 2.5 M
where,	P	=	pulling force in Newtons
	M	=	mass of animal inkg

One method to convert animate energy to fuel equivalent is to estimate the quantity of diesel that would be required if all animal labour were to be replaced by tractors and irrigation pumps. Table A.5 shows the estimated traction power of several types of animal when operating farm equipment at different speeds.

A.8 Assembling the Data

All energy data items need to be organized according to the structure of the database. Data assembling takes place within each module of the database. The main tasks involved are as follow.

Table A.5: Traction Power of Draught Animals

Type of Animal	Weight	Speed	Low Speed Traction		Speed	High Speed Traction	
	(kg)	(km/h)	(Newton)	W	(km/h)	(Newton)	(W)
Bull							
- Light	210	2.4	330	220	4.0	198	220
- Medium	450	2.4	660	440	4.0	468	520
- Heavy	900	2.4	1215	810	4.0	864	960
Water Buffalo							
- Light	400	2.4	550	370	3.2	416	370
- Medium	650	2.4	885	590	3.2	664	590
- Heavy	900	2.4	1215	810	3.2	911	810

Source : Wu and Lu 1988, adopted by Romani et al. 1995.

Validation: All data have to be validated through cross checks and use of pre-defined error ranges. Cross checks should be done to ensure internal consistency and plausibility, while the latter has more to do with comparing similar data from various sources. The aim of all validation is to achieve as much accuracy as possible subject to the practical limits of time and cost.

Compilation and Collation: Compilation involves the preparation of individual data sets into standardised data expressions (aggregation and calculation of percentages and ratios). Collation involves the matching of individual data sets into homogeneous groups.

Tabulation: Tabulation involves the organization of processed data into tables according to pre-defined formats (columns and rows). The most significant aspect of tabulation in an energy database is the preparation of energy commodity accounts which follow the energy chain of each primary energy source up to its transformation into final energy. The order of columns and rows in an energy commodity account will be similar to those in an energy balance table (which will be discussed later). The principal difference between the two is that energy sources are measured in their original units in an energy commodity account, whereas they are converted into a common energy measure in an energy balance table. The last link in the energy chain, i.e., transformation of final energy into useful energy by end-use appliance, is not shown in an energy commodity account.

Interpretation: Interpreting the assembled data is preparatory to final presentation. Interpretation requires the application of statistical and econometric tools, besides having a 'feel' for the plausibility of the data.

A.9 Presenting the Data

The main summary outputs of the energy database can be presented in tabular or graphic form. The tabular summary is known as an energy balance table, while the latter is a reference energy system. Both have their advantages and disadvantages.

Energy Balance Table

An energy balance table is a tabular presentation of all the energy flows in a chosen area (such as the HKH region) from primary energy through intermediate transformations to final energy. A simplified energy balance table is shown in Table A.6. The logic of the table, i.e., the arrangement of columns and rows, can be more readily understood by referring to the energy chain concept illustrated in Figure A.1. Some of the distinctive features are as follow.

- Energy sources are represented by the column headings.
- Energy flows (including transformations and final allocations to demand sectors) are represented by the row headings.
- Energy sources are first divided into primary and secondary energy, with some energy sources being consumed in direct form as primary energy (fuelwood, animal dung) as well as being transformed into higher energy forms for consumption as secondary energy.
- Primary energy is classified into conventional traditional, and non-conventional energy and then further disaggregated into individual energy sources.
- Secondary energy is classified into conventional and non-conventional energy. All conventional energy, including grid electricity, is treated as secondary energy. Non-conventional energy is divided into decentralised electricity, gaseous fuels, liquid fuels, and solid fuels.
- All energy sources that are imported from outside the HKH areas are under imports, and those exported from the HKH areas are shown under exports (fuelwood and hydroelectricity supplies to the urban plains).

The energy balance table is the most widely-used method of presenting the energy situation of a particular area or country. Its main advantage is that it provides a numerical summary of the entire energy situation and offers an excellent basis for compiling time-series data. Its principal disadvantages are: i) it does not explicitly identify the extent of loss at each stage of the energy chain and can also hide the levels of efficiency of individual transformation activities; and ii) energy supply sources and energy demand sectors cannot be fully disaggregated if the numbers of rows and columns are to be kept within manageable limits. For example, many biomass resources of significance may be shown under 'other biomass' and energy end uses may be ignored.

Table A.6: Typical Energy Balance Table (case example for Nepal, FY 1994/95)

Units: thousand GJ

	Primary Energy															
	Traditional Energy							Conventional Energy			Non-conventional Energy					Total
Energy Type Sectors	Fuel-wood	Agricultural Residues	Animal Waste	Industrial Waste	Other Biomass	Human	Animal	Coal/ Coke	Crude Oil	Natural Gas	Solar	Wind	Small Hydro	Geo-Thermal	Grid Electricity	
Primary Energy Production	210244	9762	17026	0	16	0	0	0	0	0	0	0	0	0	3319	240367
Import + from bunker	0	0	0	0	0	0	0	2840	0	0	0	0	0	0	396	3236
Export + to bunker	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-153	-153
Primary Energy Supply	210244	9762	17026	0	16	0	0	2840	0	0	0	0	0	0	3562	243450
Transformation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transformation Loss	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary Energy Supply	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T & D and Other Losses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-953	-953
Total Final Energy Supply	210244	9762	17026	0	16	0	0	2840	0	0	0	0	0	0	2609	242498
Residential	202306	9452	17026	0	0	0	0	14	0	0	0	0	0	0	1025	229824
Rural	192152	8186	15537	0	0	0	0	11	0	0	0	0	0	0	236	216122
Urban	10154	1266	1490	0	0	0	0	3	0	0	0	0	0	0	789	13703
Commercial/Inst	761	5	0	0	12	0	0	286	0	0	0	0	0	0	371	1436
Industrial	7177	305	0	0	4	0	0	2523	0	0	0	0	0	0	1088	11096
Agricultural	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	80
Transport	0	0	0	0	0	0	0	16	0	0	0	0	0	0	5	21
Others	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	40
Total	**210244**	**9762**	**17026**	**0**	**16**	**0**	**0**	**2840**	**0**	**0**	**0**	**0**	**0**	**0**	**2609**	**242498**

Table A.6: continued..

Energy Type Sectors	Secondary Energy													
	Conventional Energy								Non-Conventional Energy					
	Diesel	Kero-sene	Motor Spirit	LPG	Aviation Turbine Fuel	FO	Other Oil Pro-ducts*	Grid Electricity	Decen-tralized Elec +	Gaseous Fuel	Liquid Fuel	Solid Fuel	Total	Total
Primary Energy Production	0	0	0	0	0	0	0	0	0	349	0	0	349	240717
Import + from bunker	8670	6432	1298	525	1320	0	1636	0	0	0	0	0	19881	23117
Export + to bunker	-533	-438	-100	0	-111	0	0	0	0	0	0	0	-1181	-1334
Primary Energy Supply	8138	5994	1198	525	1209	0	1636	0	0	349	0	0	19050	262500
Transformation	0	0	0	0	0	0	-1029	0	0	0	0	0	-1029	-1029
Transformation Loss	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary Energy Supply	0	0	0	0	0	0	0	306	0	0	0	0	306	306
T & D and Other Losses	0	0	0	0	0	0	0	-82	0	0	0	0	-82	-1034
Total Final Energy Supply	8138	5994	1198	525	1209	0	607	224	0	349	0	0	18245	259149
Residential	0	4255	0	308	0	0	0	88	0	349	0	0	5001	234826
Rural	0	2973	0	1	0	0	0	20	0	344	0	0	3338	219460
Urban	0	1282	0	308	0	0	0	68	0	5	0	0	1663	15366
Commercial	0	1654	0	217	0	0	84	32	0	0	0	0	1987	3423
Industrial	991	85	44	0	0	0	261	93	0	0	0	0	1474	12571
Agricultural	1948	0	0	0	0	0	0	7	0	0	0	0	1955	2035
Transport	5198	0	1154	0	1209	0	0	0	0	0	0	0	7562	7584
Others	0	0	0	0	0	0	261	3	0	0	0	0	265	305
Total	8138	5994	1198	525	1209	0	607	224	0	349	0	0	18245	260743

Notes:

Elec. = electricity; FO = furnace oil; LPG = liquefied pressure gas; T & D = transport and delivery

* Other Oil Products includes FURNAC OIL, LDO, and others

\+ Data not available

1. Traditional and non-conventional energy source categories could be increased to include other major energy sources (e.g., rice husks, straw, and geothermal)
2. Gaseous fuels shown under secondary energy (non-conventional) would include such things as biogas and producer gas.
3. Liquid fuels shown under secondary energy (non-conventional) would include such things as methanol and ethanol.
4. Solid fuels shown under secondary energy (non-conventional) would include such things as charcoal and briquettes.
5. Energy demand categories could be increased to include sectors such as high, middle, and low income households, farming, agro-based and non-agro based industries.
6. Traditional and non-conventional energy sources produced within the rural energy system but sold in urban markets are shown as exports.

Reference Energy System (RES)

The reference energy system (RES) provides a physical representation of energy flows from extraction to final consumption by end-use technologies, through graphic presentation. The model helps to provide an insight into energy resource allocation and the mix of technologies needed to satisfy a specified set of energy demands.

The starting point for creating a better understanding of an energy system is the structure of the energy system. This structure, which describes the parts of the energy system and their interactions, is best represented by an RES. The RES includes all the energy sources that are exploited, all the intermediate forms into which these sources are transformed to enhance the convenience with which they are utilised, and the end-use devices that are used to obtain the services provided — cooking, lighting, process and space heating, shaft power. Moreover, the RES must include both the qualitative and quantitative descriptions of the energy system. A typical RES emphasising traditional energy sources is shown in Figure A.2.

The main calculations needed for developing a reference energy system are:

for each link point: sum of energy flow in = sum of energy flow out

$$\sum X = o$$

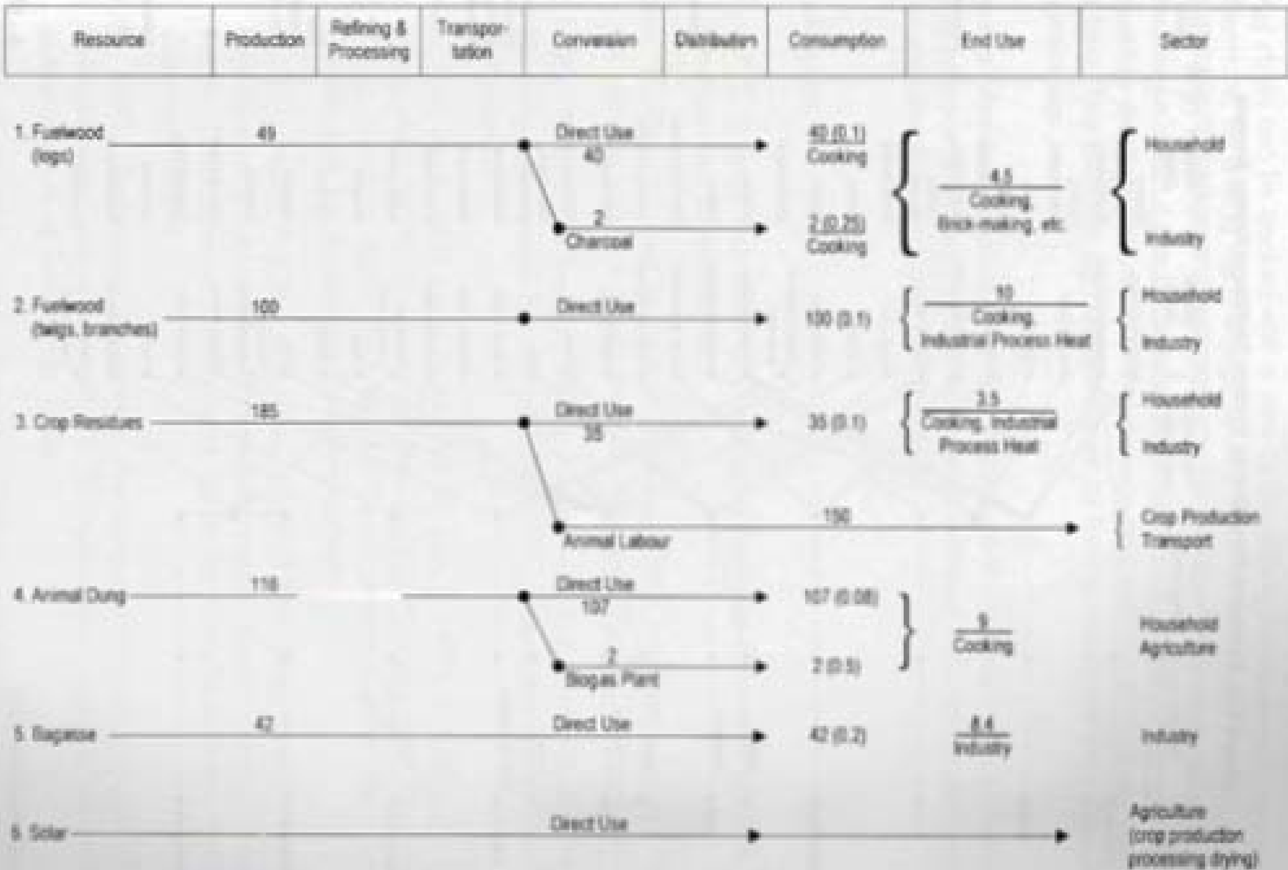
for each process:
energy output = $\eta_{process}$ * energy input

$$X_{out} = \eta_{process} * X_{in}$$

This process can be clearly understood from Figure A.2 where the sum of energy flow equals the number indicated for each resource under 'production'. Transformation losses are shown only under conversion for the sake of simplicity, but they could also be shown under other intermediate stages of the energy chain (refining and processing, transportation and distribution). The losses equal the number against a diagonal line minus the number against the following horizontal line. Further, the efficiency coefficients of end-use appliances/technologies are indicated under 'consumption'. For example, the loss incurred in transforming nine units of fuelwood into charcoal equals seven units. When the remaining two units are used in a cooking stove in the form of charcoal, the useful energy derived would equal 05 units since the efficiency coefficient of the cooking stove is 0.25.

Figure A.3 illustrates how this technique can be extended to incorporate various types of end-use equipment/appliances. It also shows how each energy source can be linked to multiple end uses.

Figure A.2: Reference Rural Energy System: Traditional Energy Sources

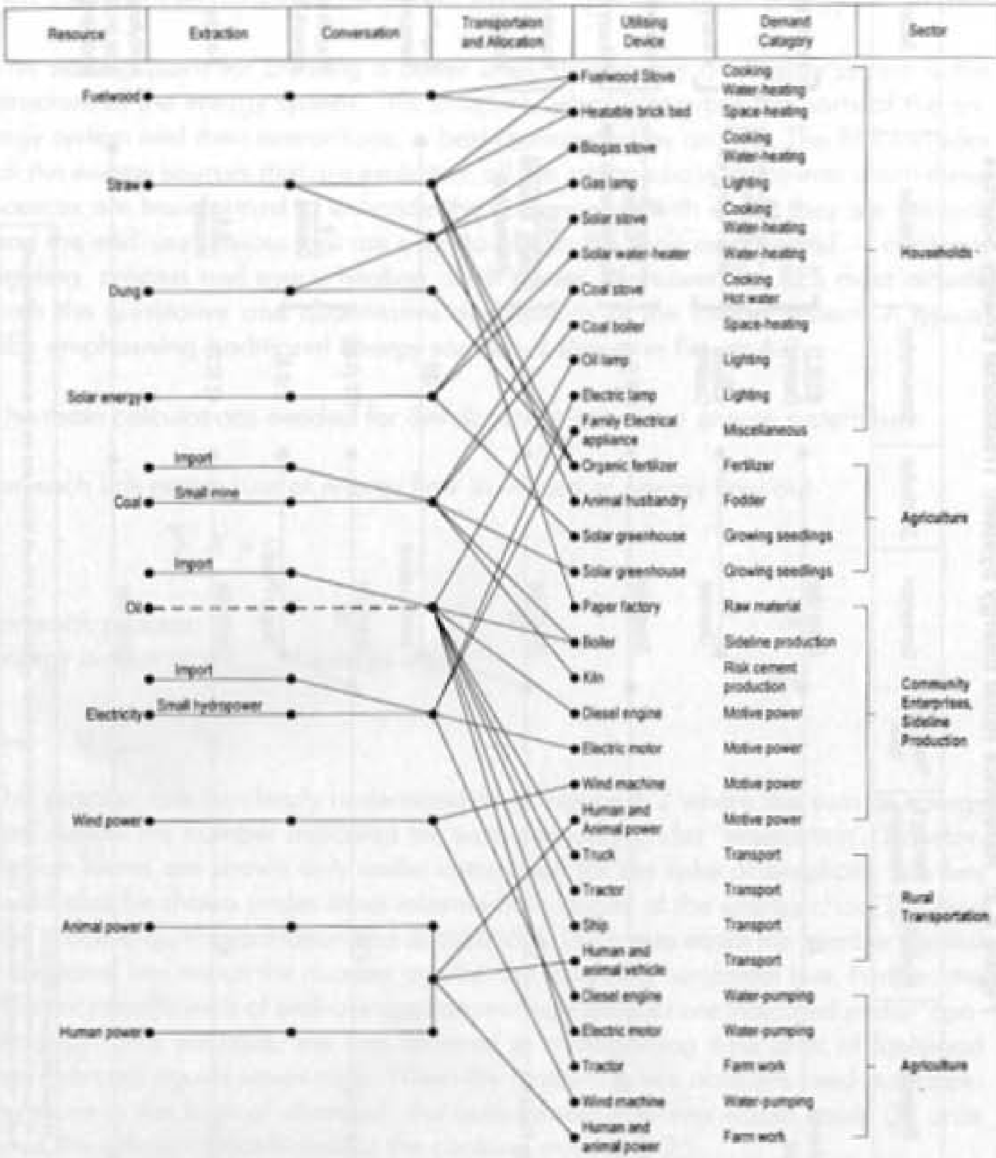


Notes: 1. All flows are shown in MTOE

2. All figures in parentheses denote efficiency coefficients of conversion processes or end-use devices and are for illustrative purposes only

Source: Bhatia, 1985 adapted by Ramani et al. 1995

Figure A.3: Reference Rural Energy System: Traditional Energy Sources



Source: *Ramani et al. (1995)*

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The reference energy system is useful for visualising the dynamic process of energy flows. The main advantage of the RES is that losses in conversion and utilisation are shown explicitly at each stage of the energy chain. Therefore, the efficiency of each energy chain can be tracked with a view to identifying improvement opportunities. Furthermore, by linking each energy source to all its end uses, the technique also allows energy substitution opportunities to be identified. The main disadvantage of the technique is that it can become quite complex and possibly incomprehensible if all possible disaggregations by energy source and end-use activity are pursued to their limit. This problem can be addressed by having supplementary diagrams for sub-processes.

From the above discussions it is clear that both a reference energy system and energy balance table are needed in order to arrive at sufficient understanding of the energy situation in a particular location.

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Annex B

Energy Tables, FY 1994/95

Final Energy Consumption Pattern
Country: China   Region: HKH
Year: 1994-95

Descriptions	Fuelwood Tonnes	Agric Residue Tonnes	Animal Dung Tonnes	Total Biomass Tonnes of Fe	Renewable TOE	Coal/ Coke Tonnes	Petroleum Fuels TOE	Gas Tonne	Electricity GWh
Domestic - Rural - Urban	12053589	6900000	5134529	20610856	983	5863530	308760	1478750	6188
Comm./Institutional	807456	600416	1185304	2034106	393	1871124	85922	1177540	399
Industrial	2106000	1566000	0	3287533	103949	4880250	224100	3071250	3341
Agriculture	0	0	0	0	26	121416	5575	76410	83
Transport	0	0	0	0	0	35279	281650	2220215	2415
Total	14967045	9066416	6319833	25932495	105351	12771600	906007	8024165	12426

Descriptions Unit: per Capita	Fuelwood kg	Agric Residue kg	Animal Dung kg	Total Biomass kg of Fe	Renewables kg OE	Coal/ Coke kg	Petroleum Fuels kg OE	Gas kg	Electricity kWh
Domestic - Rural - Urban	612	350	261	1046	0	298	16	75	314
Comm./Institutional	41	30	60	103	0	95	4	60	20
Industrial	107	79	0	167	5	248	11	156	170
Agriculture	0	0	0	0	0	6	0	4	4
Transport	0	0	0	0	0	2	14	113	123
Total	760	460	321	1316	5	648	46	407	631

Final Energy Consumption Pattern
Country: China Region: HKH
Year: 1994-95

Descriptions	Fuelwood	Agric Residue	Animal Dung	Total Biomass	Renewable	Coal/ Coke	Petroleum Fuels	Gas	Electricity	Total Commercial	Total Energy
Unit: 000' GJ											
Domestic **- Rural** **- Urban**	201295	86940	55966	344201	42	147761	13302	1490	22275	184828	529072
Comm./Instit.	13485	7565	12920	33970	17	47152	3702	1187	1435	53475	87462
Industrial	35170	19732	0	54902	4478	122982	9655	3095	12029	147761	207141
Agriculture	0	0	0	0	1	3060	240	77	299	3676	3677
Transport	0	0	0	0	0	889	12134	2237	8695	23956	23956
Total	249950	114237	68886	433073	4539	321844	39033	8087	44733	413697	851308

Descriptions	Fuelwood	Agric Residue	Animal Dung	Total Biomass	Renewable	Coal/ Coke	Petroleum Fuels	Gas	Electricity	Total Commercial	Total Energy
Unit: MJ per Capita											
Domestic **- Rural** **- Urban**	10218	4413	2841	17472	2	7501	675	76	1131	9382	26857
Comm./Inst.	684	384	656	1724	1	2394	188	60	73	2714	4440
Industrial	1785	1002	0	2787	227	6243	490	157	611	7501	10515
Agriculture	0	0	0	0	0	155	12	4	15	187	187
Transport	0	0	0	0	0	45	616	114	441	1216	1216
Total	12688	5799	3497	21983	230	16337	1981	410	2271	21000	43214

Final Energy Consumption Pattern
Country: China Region: HKH
Year: 1994-95

Descriptions	Fuelwood	Agric. Residue	Animal Dung	Total Biomass	Renewable	Coal/ Coke	Petroleum Fuels	Gas	Electricity	Total Commercial	Total Energy
Unit: Row-wise Percentage											
Domestic **- Rural** **- Urban**	38.0%	16.4%	10.6%	65.1%	0.0%	27.9%	2.5%	0.3%	4.2%	34.9%	100.0%
Comm./Inst.	15.4%	8.6%	14.8%	38.8%	0.0%	53.9%	4.2%	1.4%	1.6%	61.1%	100.0%
Industrial	17.0%	9.5%	0.0%	26.5%	2.2%	59.4%	4.7%	1.5%	5.8%	71.3%	100.0%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	83.2%	6.5%	2.1%	8.1%	100.0%	100.0%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	3.7%	50.7%	9.3%	36.3%	100.0%	100.0%
Total	29.4%	13.4%	8.1%	50.9%	0.5%	37.8%	4.6%	0.9%	5.3%	48.6%	100.0%

Descriptions	Fuelwood	Agric. Residue	Animal Dung	Total Biomass	Renewable	Coal/ Coke	Petroleum Fuels	Gas	Electricity	Total Commercial	Total Energy
Unit: Column-wise Percentage											
Domestic **- Rural** **- Urban**	80.5%	76.1%	81.2%	79.5%	0.9%	45.9%	34.1%	18.4%	49.8%	44.7%	62.1%
Comm./Inst.	5.4%	6.6%	18.8%	7.8%	0.4%	14.7%	9.5%	14.7%	3.2%	12.9%	10.3%
Industrial	14.1%	17.3%	0.0%	12.7%	98.7%	38.2%	24.7%	38.3%	26.9%	35.7%	24.3%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.6%	1.0%	0.7%	0.9%	0.4%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	31.1%	27.7%	19.4%	5.8%	2.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Final Energy Consumption Pattern
Country India Region: Mountains
Year: 1994/95

Descriptions Unit per Capita	Fuelwood kg	Charcoal kg	Agric. Residue kg	Animal Dung kg	Total Biomass kg of Fe	Coal/ Coke kg	Petroleum Fuels kg OE	Natural Gas cft	Electricity kWh
Domestic	629	0	96	82	658	0	15	0	58
Comm/Institutional	19	0	0	0	20	0	22	0	29
Industrial	42	1	9	0	52	2	11	0	96
Agriculture	0	0	0	0	0	0	3	0	22
Transport	0	0	0	0	0	0	25	0	0
Total	690	2	105	82	730	2	76	0	204

Descriptions Natural Unit	Fuelwood Tonnes	Charcoal Tonnes	Agric. Residue Tonnes	Animal Dung Tonnes	Total Biomass Tonnes of Fe	Coal/ Coke Tonnes	Petroleum Fuels TOE	Natural Gas Mcft	Electricity GWh
Domestic	20708412	847	3160288	2687529	21684291	9563	506068	0	1912
Comm/Institutional	630854	13345	0	0	653948	10721	715316	0	955
Industrial	1391752	44148	307128	0	1699877	49465	351373	0	3158
Agriculture	0	0	0	0	0	0	108875	0	709
Transport	0	0	0	0	0	0	818375	0	0
Total	22731018	58341	3467415	2687529	24038116	69749	2500007	0	6733

Final Energy Consumption Pattern
Country India Region: Mountains
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Units: MJ per Capita											
Domestic	10500	1	1209	889	12599	7	662	0	209	878	13478
Comm/inst.	320	12	0	0	332	8	936	0	104	1048	1380
Industrial	706	39	117	0	862	38	460	0	345	843	1705
Agriculture	0	0	0	0	0	0	142	0	77	220	220
Transport	0	0	0	0	0	0	1070	0	0	1070	1070
Total	11526	51	1327	889	13793	53	3270	0	736	4060	17852

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Units: '000 GJ											
Domestic	345830	24	39820	29294	414969	241	21803	0	6883	28926	443895
Comm/inst.	10535	386	0	0	10921	270	30817	0	3437	34524	45445
Industrial	23242	1276	3870	0	28388	1247	15138	0	11370	27754	56142
Agriculture	0	0	0	0	0	0	4691	0	2551	7241	7241
Transport	0	0	0	0	0	0	35257	0	0	35257	35257
Total	379608	1686	43689	29294	454278	1758	107706	0	24240	133704	587981

Final Energy Consumption Pattern

Country India Region: Mountains
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Row-wise Percentage											
Domestic	77.9%	0.0%	9.0%	6.6%	93.5%	0.1%	4.9%	0.0%	1.6%	6.5%	100.0%
Comm/Inst.	23.2%	0.8%	0.0%	0.0%	24.0%	0.6%	67.8%	0.0%	7.6%	76.0%	100.0%
Industrial	41.4%	2.3%	6.9%	0.0%	50.6%	2.2%	27.0%	0.0%	20.3%	49.4%	100.0%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	64.8%	0.0%	35.2%	100.0%	100.0%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%	100.0%
Total	64.6%	0.3%	7.4%	5.0%	77.3%	0.3%	18.3%	0.0%	4.1%	22.7%	100.0%

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Column-wise Percentage											
Domestic	91.1%	1.5%	91.1%	100.0%	91.3%	13.7%	20.2%		100.0%	21.6%	75.5%
Comm/Inst.	2.8%	22.9%	0.0%	0.0%	2.4%	15.4%	28.6%		100.0%	25.8%	7.7%
Industrial	6.1%	75.7%	8.9%	0.0%	6.2%	70.9%	14.1%		100.0%	20.8%	9.5%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.4%		100.0%	5.4%	1.2%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	32.7%			26.4%	6.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%

Final Energy Consumption Pattern
Country India Region: Eastern Mountains
Year: 1994/95

Descriptions	Fuelwood kg	Charcoal kg	Agric. Residue kg	Animal Dung kg	Total Biomass kg of Fe	Coal/ Coke kg	Petroleum Fuels kgOE	Natural Gas cft	Electricity kWh
Unit per Capita									
Domestic	694	0	135	73	627	0	13		15
Comm/Institutional	16	1	0	0	18	0	29		34
Industrial	49	0	0	0	49	0	10		70
Agriculture	0	0	0	0	0	0	2		15
Transport	0	0	0	0	0	0	21		0
Total	758	1	135	73	693	1	74	0	134

Descriptions	Fuelwood Tonnes	Charcoal Tonnes	Agric. Residue Tonnes	Animal Dung Tonnes	Total Biomass Tonnes of Fe	Coal/ Coke Tonnes	Petroleum Fuels TOE	Natural Gas Mcft	Electricity GWh
Natural Unit									
Domestic	10168301	469	1979410	1070347	9197038	4399	183279	0	220
Comm/Institutional	237529	11730	0	0	257828	5865	428139	0	499
Industrial	712588	0	0	0	712588	3666	146623	0	1023
Agriculture	0	0	0	0	0	0	29325	0	220
Transport	0	0	0	0	0	0	300577	0	0
Total	11118418	12199	1979410	1070347	10167454	13929	1087942	0	1962

Final Energy Consumption Pattern
Country India Region: Eastern Mountains
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Units: MJ per Capita											
Domestic	11581	1	1701	796	14079	8	539	0	54	600	14679
Comm/Inst.	271	23	0	0	294	10	1258	0	123	1391	1684
Industrial	812	0	0	0	812	6	431	0	251	688	1500
Agriculture	0	0	0	0	0	0	86	0	54	140	140
Transport	0	0	0	0	0	0	883	0	0	883	883
Total	12664	24	1701	796	15184	24	3197	0	482	3702	18887

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Units: '000 GJ											
Domestic	169811	14	24941	11667	206432	111	7896	0	792	8799	215230
Comm/Inst.	3967	339	0	0	4306	148	18445	0	1798	20391	24697
Industrial	11900	0	0	0	11900	92	6317	0	3681	10091	21991
Agriculture	0	0	0	0	0	0	1263	0	792	2055	2055
Transport	0	0	0	0	0	0	12950	0	0	12950	12950
Total	185678	353	24941	11667	222637	351	46871	0	7063	54285	276923

Final Energy Consumption Pattern
Country India Region: Eastern Mountains
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Row-wise Percentage											
Domestic	78.9%	0.0%	11.6%	5.4%	95.9%	0.1%	3.7%	0.0%	0.4%	4.1%	100.0%
Comm/Inst.	16.1%	1.4%	0.0%	0.0%	17.4%	0.6%	74.7%	0.0%	7.3%	82.6%	100.0%
Industrial	54.1%	0.0%	0.0%	0.0%	54.1%	0.4%	28.7%	0.0%	16.7%	45.9%	100.0%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	61.5%	0.0%	38.5%	100.0%	100.0%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%	100.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	#DIV/0!	100.0%	100.0%	100.0%

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Column-wise Percentage											
Domestic	91.5%	3.8%	100.0%	100.0%	92.7%	31.6%	16.8%		11.2%	16.2%	77.7%
Comm/Inst.	2.1%	96.2%	0.0%	0.0%	1.9%	42.1%	39.4%		25.5%	37.6%	8.9%
Industrial	6.4%	0.0%	0.0%	0.0%	5.3%	26.3%	13.5%		52.1%	18.6%	7.9%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.7%		11.2%	3.8%	0.7%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	27.6%		0.0%	23.9%	4.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%

Final Energy Consumption Pattern
Country India Region: Western Mountains
Year: 1994/95

Descriptions	Fuelwood kg	Charcoal kg	Agric. Residue kg	Animal Dung kg	Total Biomass kg of Fe	Coal/ Coke kg	Petroleum Fuels kgOE	Natural Gas cft	Electricity kWh
Unit per Capita									
Domestic	577	0	65	88	683	0	18	0	93
Comm./Institutional	22	0	0	0	22	0	16	0	25
Industrial	37	2	17	0	54	3	11	0	117
Agriculture	0	0	0	0	0	0	4	0	27
Transport	0	0	0	0	0	0	28	0	0
Total	635	3	81	88	759	3	77	0	261

Descriptions	Fuelwood Tonnes	Charcoal Tonnes	Agric. Residue Tonnes	Animal Dung Tonnes	Total Biomass Tonnes of Fe	Coal/ Coke Tonnes	Petroleum Fuels TOE	Natural Gas Mcft	Electricity GWh
Natural Unit									
Domestic	10540111	378	1180878	1617181	12487252	5164	322790	0	1692
Comm/Institutional	393325	1615	0	0	396120	4856	287177	0	455
Industrial	679164	44148	307128	0	987290	45800	204751	0	2136
Agriculture	0	0	0	0	0	0	79550	0	489
Transport	0	0	0	0	0	0	517798	0	0
Total	11612600	46142	1488006	1617181	13870662	55820	1412065	0	4771

Final Energy Consumption Pattern

Country India Region: Western Mountains
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Units: MJ per Capita											
Domestic	9632	1	814	965	11412	7	761	0	333	1101	12513
Comm/inst.	359	3	0	0	362	7	677	0	90	773	1135
Industrial	621	70	212	0	902	63	483	0	421	967	1869
Agriculture	0	0	0	0	0	0	188	0	96	284	284
Transport	0	0	0	0	0	0	1221	0	0	1221	1221
Total	10613	73	1026	965	12676	77	3329	0	940	4346	17022

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Units: '000 GJ											
Domestic	176020	11	14879	17627	208537	130	13906	0	6091	20128	228665
Comm/inst.	6569	47	0	0	6615	122	12372	0	1639	14133	20748
Industrial	11342	1276	3870	0	16488	1154	8821	0	7688	17664	34151
Agriculture	0	0	0	0	0	0	3427	0	1759	5186	5186
Transport	0	0	0	0	0	0	22308	0	0	22308	22308
Total	193930	1333	18749	17627	231640	1407	60835	0	17177	79419	311059

Final Energy Consumption Pattern
Country India Region: Western Mountains
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Row-wise Percentage											
Domestic	77.0%	0.0%	6.5%	7.7%	91.2%	0.1%	6.1%	0.0%	2.7%	8.8%	100.0%
Comm/Inst.	31.7%	0.2%	0.0%	0.0%	31.9%	0.6%	59.6%	0.0%	7.9%	68.1%	100.0%
Industrial	33.2%	3.7%	11.3%	0.0%	48.3%	3.4%	25.8%	0.0%	22.5%	51.7%	100.0%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	66.1%	0.0%	33.9%	100.0%	100.0%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%	100.0%
Total	62.3%	0.4%	6.0%	5.7%	74.5%	0.5%	19.6%	0.0%	5.5%	25.5%	100.0%

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Column-wise Percentage											
Domestic	90.8%	0.8%	79.4%	100.0%	90.0%	9.3%	22.9%		35.5%	25.3%	73.5%
Comm/Inst.	3.4%	3.5%	0.0%	0.0%	2.9%	8.7%	20.3%		9.5%	17.8%	6.7%
Industrial	5.8%	95.7%	20.6%	0.0%	7.1%	82.0%	14.5%		44.8%	22.2%	11.0%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.6%		10.2%	6.5%	1.7%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	36.7%		0.0%	28.1%	7.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%

Final Energy Consumption Pattern

Country Nepal Region: Nepal

Year: 1994/95

Descriptions	Fuelwood Tonnes	Charcoal Tonnes	Agric. Residue Tonnes	Animal Dung Tonnes	Total Biomass Tonnes of Fe	Coal/ Coke Tonnes	Petroleum Fuels TOE	Natural Gas Mcft	Electricity GWh
Domestic	12114158	0	750177	1562050	13699701	552	105930	0	309
- Rural	11506105	0	649704	1425370	12926632	425	69025	0	71
- Urban	608053	0	100473	136680	773069	127	36905	0	238
Comm./Institutional	45577	429	391	0	46615	11352	47430	0	112
Industrial	429743	0	24192	0	447996	100130	29982	0	328
Agriculture	0	0	0	0	0	0	45216	0	24
Transport	0	0	0	0	0	646	153831	0	2
Total	12589478	429	774760	1562050	14194312	112680	382390	0	775

Descriptions	Fuelwood kg	Charcoal kg	Agric. Residue kg	Animal Dung kg	Total Biomass kg of Fe	Coal/ Coke kg	Petroleum Fuels kgOE	Natural Gas cft	Electricity kWh
Domestic	595	0	37	77	673	0	5	0	15
- Rural	636	0	36	79	714	0	4	0	4
- Urban	268	0	44	60	341	0	16	0	105
Comm./Institutional	2	0	0	0	2	1	2	0	5
Industrial	21	0	1	0	22	5	1	0	16
Agriculture	0	0	0	0	0	0	2	0	1
Transport	0	0	0	0	0	0	8	0	0
Total	618	0	38	77	697	6	19	0	38

Final Energy Consumption Pattern
Country Nepal Region: Nepal
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: 000' GJ											
Domestic	202306	0	9452	17026	228785	14	4564	0	1114	5691	234476
- Rural	192152	0	8186	15537	215875	11	2974	0	256	3241	219116
- Urban	10154	0	1266	1490	12910	3	1590	0	857	2450	15361
Comm./Inst.	761	12	5	0	778	286	2043	0	403	2732	3511
Industrial	7177	0	305	0	7482	2523	1292	0	1181	4996	12478
Agriculture	0	0	0	0	0	0	1948	0	87	2035	2035
Transport	0	0	0	0	0	16	6627	0	6	6649	6649
Total	210244	12	9762	17026	237045	2840	16474	0	2790	22104	259149

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: MJ per Capita											
Domestic	9935	0	464	836	11236	1	224	0	55	279	11515
- Rural	10619	0	452	859	11930	1	164	0	14	179	12109
- Urban	4478	0	558	657	5693	1	701	0	378	1081	6774
Comm./Inst.	37	1	0	0	38	14	100	0	20	134	172
Industrial	352	0	15	0	367	124	63	0	58	245	613
Agriculture	0	0	0	0	0	0	96	0	4	100	100
Transport	0	0	0	0	0	1	325	0	0	327	327
Total	10325	1	479	836	11641	139	809	0	137	1086	12727

Prepared by: K. Rijal

Final Energy Consumption Pattern
Country Nepal Region: Nepal
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: Row-wise Percentage											
Domestic	86.3%	0.0%	4.0%	7.3%	97.6%	0.0%	1.9%	0.0%	0.5%	2.4%	100.0%
- Rural	87.7%	0.0%	3.7%	7.1%	98.5%	0.0%	1.4%	0.0%	0.1%	1.5%	100.0%
- Urban	66.1%	0.0%	8.2%	9.7%	84.0%	0.0%	10.4%	0.0%	5.6%	16.0%	100.0%
Comm./Inst.	21.7%	0.4%	0.1%	0.0%	22.2%	8.1%	58.2%	0.0%	11.5%	77.8%	100.0%
Industrial	57.5%	0.0%	2.4%	0.0%	60.0%	20.2%	10.4%	0.0%	9.5%	40.0%	100.0%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	95.7%	0.0%	4.3%	100.0%	100.0%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	99.7%	0.0%	0.1%	100.0%	100.0%
Total	81.1%	0.0%	3.8%	6.6%	91.5%	1.1%	6.4%	0.0%	1.1%	8.5%	100.0%

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: Column-wise Percentage											
Domestic	96.2%	0.0%	96.8%	100.0%	96.5%	0.5%	27.7%		39.9%	25.7%	90.5%
- Rural	91.4%	0.0%	83.9%	91.2%	91.1%	0.4%	18.1%		9.2%	14.7%	84.6%
- Urban	4.8%	0.0%	13.0%	8.8%	5.4%	0.1%	9.7%		30.7%	11.1%	5.9%
Comm./Inst.	0.4%	100.0%	0.1%	0.0%	0.3%	10.1%	12.4%		14.4%	12.4%	1.4%
Industrial	3.4%	0.0%	3.1%	0.0%	3.2%	88.9%	7.8%		42.3%	22.6%	4.8%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.8%		3.1%	9.2%	0.8%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	40.2%		0.2%	30.1%	2.6%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%

Final Energy Consumption Pattern
Country Nepal Region: Eastern
Year: 1994/95

Descriptions	Fuelwood Tonnes	Charcoal Tonnes	Agric. Residue Tonnes	Animal Dung Tonnes	Total Biomass Tonnes of Fe	Coal/ Coke Tonnes	Petroleum Fuels TOE	Natural Gas Mcft	Electricity GWh
Domestic	6264250	0	526609	1140815	7406175	425	72490	0	263
- Rural	5911812	0	481457	1025291	6944269	425	39638	0	43
- Urban	352438	0	45152	115524	461906	0	32851	0	220
Comm./Institutional	24944	0	391	0	25239	240	36720	0	93
Industrial	361211	0	22878	0	378472	78174	14140	0	299
Agriculture	0	0	0	0	0	0	27455	0	11
Transport	0	0	0	0	0	646	132287	0	2
Total	6650404	0	549877	1140815	7809886	79485	283092	0	667

Descriptions	Fuelwood kg	Charcoal kg	Agric. Residue kg	Animal Dung kg	Total Biomass kg of Fe	Coal/ Coke kg	Petroleum Fuels kg OE	Natural Gas cft	Electricity kWh
Domestic	532	0	45	97	629	0	6	0	22
- Rural	584	0	48	101	686	0	4	0	4
- Urban	215	0	28	70	281	0	20	0	134
Comm./Institutional	2	0	0	0	2	0	3	0	8
Industrial	31	0	2	0	32	7	1	0	25
Agriculture	0	0	0	0	0	0	2	0	1
Transport	0	0	0	0	0	0	11	0	0
Total	565	0	47	97	664	7	24	0	57

Final Energy Consumption Pattern

Country Nepal Region: Eastern

Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: 000' GJ											
Domestic	104613	0	6635	12435	123683	11	3123	0	945	4079	127762
- Rural	98727	0	6066	11176	115969	11	1708	0	153	1872	117841
- Urban	5886	0	569	1259	7714	0	1415	0	792	2207	9921
Comm./Inst.	417	0	5	0	421	6	1582	0	333	1921	2343
Industrial	6032	0	288	0	6320	1970	609	0	1078	3657	9978
Agriculture	0	0	0	0	0	0	1183	0	38	1221	1221
Transport	0	0	0	0	0	16	5699	0	6	5721	5721
Total	111062	0	6928	12435	130425	2003	12196	0	2400	16599	147024

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: MJ per Capita											
Domestic	8889	0	564	1057	10509	1	265	0	80	347	10855
- Rural	9748	0	599	1103	11450	1	169	0	15	185	11635
- Urban	3587	0	347	767	4701	0	862	0	483	1345	6046
Comm./Inst.	35	0	0	0	36	1	134	0	28	163	199
Industrial	513	0	24	0	537	167	52	0	92	311	848
Agriculture	0	0	0	0	0	0	100	0	3	104	104
Transport	0	0	0	0	0	1	484	0	0	486	486
Total	9437	0	589	1057	11082	170	1036	0	204	1410	12492

Final Energy Consumption Pattern
Country Nepal Region: Eastern
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: Row-wise Percentage											
Domestic	81.9%	0.0%	5.2%	9.7%	96.8%	0.0%	2.4%		0.7%	3.2%	100.0%
- Rural	83.8%	0.0%	5.1%	9.5%	98.4%	0.0%	1.4%		0.1%	1.6%	100.0%
- Urban	59.3%	0.0%	5.7%	12.7%	77.8%	0.0%	14.3%		8.0%	22.2%	100.0%
Comm./Inst.	17.8%	0.0%	0.2%	0.0%	18.0%	0.3%	67.5%		14.2%	82.0%	100.0%
Industrial	60.5%	0.0%	2.9%	0.0%	63.3%	19.7%	6.1%		10.8%	36.7%	100.0%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	96.9%		3.1%	100.0%	100.0%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	99.6%		0.1%	100.0%	100.0%
Total	75.5%	0.0%	4.7%	8.5%	88.7%	1.4%	8.3%		1.6%	11.3%	100.0%

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: Column-wise Percentage											
Domestic	94.2%		95.8%	100.0%	94.8%	0.5%	25.6%		39.4%	24.6%	86.9%
- Rural	88.9%		87.6%	89.9%	88.9%	0.5%	14.0%		6.4%	11.3%	80.2%
- Urban	5.3%		8.2%	10.1%	5.9%	0.0%	11.6%		33.0%	13.3%	6.7%
Comm./Institutional	0.4%		0.1%	0.0%	0.3%	0.3%	13.0%		13.9%	11.6%	1.6%
Industrial	5.4%		4.2%	0.0%	4.8%	98.4%	5.0%		44.9%	22.0%	6.8%
Agriculture	0.0%		0.0%	0.0%	0.0%	0.0%	9.7%		1.6%	7.4%	0.8%
Transport	0.0%		0.0%	0.0%	0.0%	0.8%	46.7%		0.7%	34.5%	3.9%
Total	100.0%		100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%

Final Energy Consumption Pattern
Country Nepal Region: Western
Year: 1994/95

Descriptions	Fuelwood Tonnes	Charcoal Tonnes	Agric. Residue Tonnes	Animal Dung Tonnes	Total Biomass Tonnes of Fe	Coal/ Coke Tonnes	Petroleum Fuels TOE	Natural Gas Mcft	Electricity GWh
Domestic	5849908	0	223568	421235	6293526	127	33440	0	47
- Rural	5594293	0	168247	400079	5982363	0	29387	0	29
- Urban	255616	0	55321	21155	311163	127	4054	0	18
Comm./Institutional	20633	0	0	0	20633	11112	10710	0	19
Industrial	68533	0	1315	0	69525	21956	15842	0	29
Agriculture	0	0	0	0	0	0	17762	0	13
Transport	0	0	0	0	0	0	21544	0	0
Total	5939074	0	224882	421235	6383683	33195	99298	0	108

Descriptions	Fuelwood kg	Charcoal kg	Agric. Residue kg	Animal Dung kg	Total Biomass kg of Fe	Coal/ Coke kg	Petroleum Fuels kg OE	Natural Gas cft	Electricity kWh
Domestic	681	0	26	49	732	0	4	0	5
- Rural	702	0	21	50	751	0	4	0	4
- Urban	408	0	88	34	496	0	6	0	29
Comm./Institutional	2	0	0	0	2	1	1	0	2
Industrial	8	0	0	0	8	3	2	0	3
Agriculture	0	0	0	0	0	0	2	0	2
Transport	0	0	0	0	0	0	3	0	0
Total	691	0	26	49	743	4	12	0	13

Final Energy Consumption Pattern

Country Nepal Region: Western
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: 000' GJ											
Domestic	97693	0	2817	4591	105102	3	1441	0	168	1612	106714
- Rural	93425	0	2120	4361	99905	0	1266	0	103	1369	101275
- Urban	4269	0	697	231	5196	3	175	0	65	243	5440
Comm./Inst.	345	0	0	0	345	280	461	0	70	811	1156
Industrial	1144	0	17	0	1161	553	683	0	103	1339	2500
Agriculture	0	0	0	0	0	0	765	0	49	814	814
Transport	0	0	0	0	0	0	928	0	0	928	928
Total	99183	0	2834	4591	106608	837	4278	0	390	5504	112112

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: MJ per Capita											
Domestic	11369	0	328	534	12231	0	168	0	20	188	12418
- Rural	11727	0	266	547	12541	0	159	0	13	172	12713
- Urban	6811	0	1112	368	8291	5	279	0	104	388	8679
Comm./Inst.	40	0	0	0	40	33	54	0	8	94	135
Industrial	133	0	2	0	135	64	79	0	12	156	291
Agriculture	0	0	0	0	0	0	89	0	6	95	95
Transport	0	0	0	0	0	0	108	0	0	108	108
Total	11542	0	330	534	12406	97	498	0	45	641	13047

Final Energy Consumption Pattern
Country Nepal Region: Western
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: Row-wise Percentage											
Domestic	91.5%	0.0%	2.6%	4.3%	98.5%	0.0%	1.4%		0.2%	1.5%	100.0%
- Rural	92.2%	0.0%	2.1%	4.3%	98.6%	0.0%	1.3%		0.1%	1.4%	100.0%
- Urban	78.5%	0.0%	12.8%	4.2%	95.5%	0.1%	3.2%		1.2%	4.5%	100.0%
Comm./Inst.	29.8%	0.0%	0.0%	0.0%	29.8%	24.2%	39.9%		6.0%	70.2%	100.0%
Industrial	45.8%	0.0%	0.7%	0.0%	46.4%	22.1%	27.3%		4.1%	53.6%	100.0%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	94.0%		6.0%	100.0%	100.0%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%		0.0%	100.0%	100.0%
Total	88.5%	0.0%	2.5%	4.1%	95.1%	0.7%	3.8%		0.3%	4.9%	100.0%

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: Column-wise Percentage											
Domestic	98.5%		99.4%	100.0%	98.6%	0.4%	33.7%		43.2%	29.3%	100.0%
- Rural	94.2%		74.8%	95.0%	93.7%	0.0%	29.6%		26.5%	24.9%	100.0%
- Urban	4.3%		24.6%	5.0%	4.9%	0.4%	4.1%		16.7%	4.4%	100.0%
Comm./Inst.	0.3%		0.0%	0.0%	0.3%	33.5%	10.8%		17.9%	14.7%	100.0%
Industrial	1.2%		0.6%	0.0%	1.1%	66.1%	16.0%		26.4%	24.3%	100.0%
Agriculture	0.0%		0.0%	0.0%	0.0%	0.0%	17.9%		12.5%	14.8%	100.0%
Transport	0.0%		0.0%	0.0%	0.0%	0.0%	21.7%		0.0%	16.9%	100.0%
Total	100.0%		100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%

Final Energy Consumption Pattern

Country Pakistan Region: Mountains
Year: 1994/95

Descriptions	Fuelwood Tonnes	Charcoal Tonnes	Agric Residue Tonnes	Animal Dung Tonnes	Total Biomass Tonnes of Fe	Coal/ Coke Tonnes	Petroleum Fuels TOE	Natural Gas Mcft	Electricity GWh
Natural Unit									
Domestic	10193068	44555	979263	2586977	12697523	9896	142652	9613	3914
- Rural	9253204	38547	858013	2381298	11521536	0	95982	0	2316
- Urban	939864	6007	121250	205679	1175988	0	46669	9613	1597
Commercial	0	0	0	0	0	0	0	2437	517
Institutional	0	0	0	0	0	0	29621	0	568
Industrial	559800	9175	285535	0	791111	200581	200892	9353	2928
Agriculture	0	0	0	0	0	0	50485	0	1281
Transport	0	0	0	0	0	0	928900	0	0
Total	10752868	53729	1264799	2586977	13488634	210477	1352549	21403	9207

Descriptions	Fuelwood kg	Charcoal kg	Agric Residue kg	Animal Dung kg	Total Biomass kg of Fe	Coal/ Coke kg	Petroleum Fuels kg OE	Natural Gas cft	Electricity kWh
Unit per Capita									
Domestic	343	2	33	87	428	0	5	324	132
- Rural	367	2	34	94	457	0	4	0	92
- Urban	211	1	27	46	264	0	10	2160	359
Commercial	0	0	0	0	0	0	0	82	17
Institutional	0	0	0	0	0	0	1	0	19
Industrial	19	0	10	0	27	7	7	315	99
Agriculture	0	0	0	0	0	0	2	0	43
Transport	0	0	0	0	0	0	31	0	0
Total	362	2	43	87	455	7	46	721	310

Final Energy Consumption Pattern
Country Pakistan Region: Mountains
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Units : MJ per Capita											
Domestic	5736	43	416	950	7146	8	207	326	475	1017	8163
- Rural	6126	44	429	1029	7628	0	164	0	331	495	8122
- Urban	3527	39	343	504	4413	0	452	2177	1292	3921	8335
Commercial	0	0	0	0	0	0	0	83	63	146	146
Institutional	0	0	0	0	0	0	43	0	69	112	112
Industrial	315	9	121	0	445	170	292	318	355	1135	1580
Agriculture	0	0	0	0	0	0	73	0	155	229	229
Transport	0	0	0	0	0	0	1349	0	0	1349	1349
Total	6051	52	537	950	7591	179	1964	727	1117	3986	11577

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Unit: '000 GJ											
Domestic	170224	1288	12339	28198	212049	249	6146	9688	14089	30172	242221
- Rural	154529	1114	10811	25956	192410	0	4135	0	8339	12474	204884
- Urban	15696	174	1528	2242	19639	0	2011	9688	5750	17448	37087
Commercial	0	0	0	0	0	0	0	2456	1861	4318	4318
Institutional	0	0	0	0	0	0	1276	0	2045	3321	3321
Industrial	9349	265	3598	0	13212	5055	8655	9425	10540	33675	46886
Agriculture	0	0	0	0	0	0	2175	0	4610	6785	6785
Transport	0	0	0	0	0	0	40019	0	0	40019	40019
Total	179573	1553	15936	28198	225260	5304	58271	21570	33146	118290	343550

Final Energy Consumption Pattern
Country Pakistan Region: Mountains
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Row-wise Percentage											
Domestic	70.3%	0.5%	5.1%	11.6%	87.5%	0.1%	2.5%	4.0%	5.8%	12.5%	100.0%
- Rural	75.4%	0.5%	5.3%	12.7%	93.9%	0.0%	2.0%	0.0%	4.1%	6.1%	100.0%
- Urban	42.3%	0.5%	4.1%	6.0%	53.0%	0.0%	5.4%	26.1%	15.5%	47.0%	100.0%
Commercial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	56.9%	43.1%	100.0%	100.0%
Institutional							100.0%		100.0%	100.0%	100.0%
Industrial	19.9%	0.6%	7.7%	0.0%	28.2%	10.8%	18.5%	20.1%	22.5%	71.8%	100.0%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	32.1%	0.0%	67.9%	100.0%	100.0%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%	100.0%
Total	52.3%	0.5%	4.6%	8.2%	65.6%	1.5%	17.0%	6.3%	9.6%	34.4%	100.0%

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Column-wise Percentage											
Domestic	94.8%		77.4%	100.0%	94.1%	4.7%	10.5%	44.9%	42.5%	25.5%	70.5%
- Rural	86.1%		67.8%	92.0%	85.4%	0.0%	7.1%	0.0%	25.2%	10.5%	59.6%
- Urban	8.7%		9.6%	8.0%	8.7%	0.0%	3.5%	44.9%	17.3%	14.8%	10.8%
Commercial	0.0%		0.0%	0.0%	0.0%	0.0%	0.0%	11.4%	5.6%	3.7%	1.3%
Institutional	0.0%		0.0%	0.0%	0.0%	0.0%	2.2%	0.0%	6.2%	2.8%	1.0%
Industrial	5.2%		22.6%	0.0%	5.9%	95.3%	14.9%	43.7%	31.8%	28.5%	13.6%
Agriculture	0.0%		0.0%	0.0%	0.0%	0.0%	3.7%	0.0%	13.9%	5.7%	2.0%
Transport	0.0%		0.0%	0.0%	0.0%	0.0%	68.7%	0.0%	0.0%	33.8%	11.6%
Total	100.0%		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Final Energy Consumption Pattern

Country Pakistan Region: Western Mountains

Year: 1994/95

Descriptions	Fuelwood Tonnes	Charcoal Tonnes	Agric. Residue Tonnes	Animal Dung Tonnes	Total Biomass Tonnes of Fe	Coal/ Coke Tonnes	Petroleum Fuels TOE	Natural Gas Mcft	Electricity GWh
Domestic	3971471	0	0	580945	4350650	7825	49291	2205	1052
- Rural	3511229	0	0	580945	3890409	0	24404	0	118
- Urban	460241	0	0	0	460241	0	24887	2205	935
Commercial	0	0	0	0	0	0	0	506	68
Institutional	0	0	0	0	0	0	9474	0	92
Industrial	101070	0	33690	0	126489	148666	37895	101	417
Agriculture	0	0	0	0	0	0	14211	0	209
Transport	0	0	0	0	0	0	217897	0	0
Total	4072541	0	33690	580945	4477139	156491	328767	2812	1837

Descriptions **Unit per Capita**	Fuelwood kg	Charcoal kg	Agric. Residue kg	Animal Dung kg	Total Biomass kg of Fe	Coal/ Coke kg	Petroleum Fuels kgOE	Natural Gas cft	Electricity kWh
Domestic	592	0	0	87	648	1	7	312	47
- Rural	635	0	0	105	704	0	4	0	21
- Urban	380	0	0	0	380	0	21	1819	169
Commercial	0	0	0	0	0	0	0	75	12
Institutional	0	0	0	0	0	0	1	0	17
Industrial	15	0	5	0	19	26	6	15	75
Agriculture	0	0	0	0	0	0	2	0	38
Transport	0	0	0	0	0	0	32	0	0
Total	607	0	5	87	667	27	49	402	189

Final Energy Consumption Pattern
Country Pakistan Region: Western Mountains
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Units : '000 GJ											
Domestic	66324	0	0	6332	72656	197	2124	2222	3787	8330	80986
- Rural	58638	0	0	6332	64970	0	1051	0	423	1475	66444
- Urban	7686	0	0	0	7686	0	1072	2222	3364	6658	14344
Commercial	0	0	0	0	0	0	0	510	244	754	754
Institutional	0	0	0	0	0	0	408	0	330	738	738
Industrial	1688	0	424	0	2112	3746	1633	102	1501	6982	9095
Agriculture	0	0	0	0	0	0	612	0	751	1363	1363
Transport	0	0	0	0	0	0	9387	0	0	9387	9387
Total	68011	0	424	6332	74768	3944	14164	2834	6613	27555	102323

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
Units : MJ per Capita											
Domestic	9843	0	0	940	10783	29	315	330	562	1236	12019
- Rural	10611	0	0	1146	11757	0	190	0	77	267	12024
- Urban	6342	0	0	0	6342	0	885	1833	2776	5494	11835
Commercial	0	0	0	0	0	0	0	76	36	112	112
Institutional	0	0	0	0	0	0	61	0	49	110	110
Industrial	251	0	63	0	314	556	242	15	223	1036	1350
Agriculture	0	0	0	0	0	0	91	0	111	202	202
Transport	0	0	0	0	0	0	1393	0	0	1393	1393
Total	10094	0	63	940	11097	585	2102	421	982	4090	15186

Final Energy Consumption Pattern
Country Pakistan Region: Western Mountains
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Row-wise Percentage											
Domestic	81.9%	0.0%	0.0%	7.8%	89.7%	0.2%	2.6%	2.7%	4.7%	10.3%	100.0%
- Rural	88.3%	0.0%	0.0%	9.5%	97.8%	0.0%	1.6%	0.0%	0.6%	2.2%	100.0%
- Urban	53.6%	0.0%	0.0%	0.0%	53.6%	0.0%	7.5%	15.5%	23.5%	46.4%	100.0%
Commercial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	67.6%	32.4%	100.0%	100.0%
Institutional	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	55.3%	0.0%	44.7%	100.0%	100.0%
Industrial	18.6%	0.0%	4.7%	0.0%	23.2%	41.2%	18.0%	1.1%	16.5%	76.8%	100.0%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	44.9%	0.0%	55.1%	100.0%	100.0%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%	100.0%
Total	66.5%	0.0%	0.4%	6.2%	73.1%	3.9%	13.8%	2.8%	6.5%	26.9%	100.0%

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Column-wise Percentage											
Domestic	97.5%			100.0%	97.2%	5.0%	15.0%	78.4%	57.3%	30.2%	79.1%
- Rural	86.2%			100.0%	86.9%	0.0%	7.4%	0.0%	6.4%	5.4%	64.9%
- Urban	11.3%			0.0%	10.3%	0.0%	7.6%	78.4%	50.9%	24.2%	14.0%
Commercial	0.0%			0.0%	0.0%	0.0%	0.0%	18.0%	3.7%	2.7%	0.7%
Institutional	0.0%			0.0%	0.0%	0.0%	2.9%	0.0%	5.0%	2.7%	0.7%
Industrial	2.5%		100.0%	0.0%	2.8%	95.0%	11.5%	3.6%	22.7%	25.3%	8.9%
Agriculture	0.0%			0.0%	0.0%	0.0%	4.3%	0.0%	11.3%	4.9%	1.3%
Transport	0.0%			0.0%	0.0%	0.0%	66.3%	0.0%	0.0%	34.1%	9.2%
Total	100.0%		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Final Energy Consumption Pattern
Country Pakistan Region: Northern Mountains
Year: 1994/95

Descriptions	Fuelwood Tonnes	Charcoal Tonnes	Agric. Residue Tonnes	Animal Dung Tonnes	Total Biomass Tonnes of Fe	Coal/ Coke Tonnes	Petroleum Fuels TOE	Natural Gas Mcft	Electricity GWh
In Natural Unit									
Domestic	6221597	44555	979263	2006032	8346873	2071	93361	7408	2862
- Rural	5741975	38547	858013	1800353	7631126	0	71579	0	2199
- Urban	479623	6007	121250	205679	715747	0	21782	7408	663
Commercial	0	0	0	0	0	0	0	1931	449
Institutional	0	0	0	0	0	0	20147	0	476
Industrial	458730	9175	251845	0	664622	51915	162997	9251	2511
Agriculture	0	0	0	0	0	0	36274	0	1072
Transport	0	0	0	0	0	0	711003	0	0
Total	6680328	53729	1231109	2006032	9011495	53986	1023782	18591	7370

Descriptions	Fuelwood kg	Charcoal kg	Agric. Residue kg	Animal Dung kg	Total Biomass kg of Fe	Coal/ Coke kg	Petroleum Fuels kgOE	Natural Gas cft	Electricity kWh
Unit per Capita									
Domestic	270	2	43	87	360	0	4	377	127
- Rural	291	2	44	91	387	NA	4	0	112
- Urban	148	2	37	64	221	NA	7	2288	205
Commercial	0	0	0	0	0	0	0	84	20
Institutional	0	0	0	0	0	0	1	0	21
Industrial	20	0	11	0	29	2	7	403	109
Agriculture	0	0	0	0	0	0	2	0	47
Transport	0	0	0	0	0	0	31	0	0
Total	290	2	54	87	389	2	45	864	324

Final Energy Consumption Pattern
Country Pakistan Region: Northern Mountains
Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial
Units: 000' GJ										
Domestic	103901	1288	12339	21866	139393	52	4022	7466	10302	21790
- Rural	95891	1114	10811	19624	127440	0	3084	0	7916	11000
- Urban	8010	174	1528	2242	11953	0	938	7466	2386	10790
Commercial	0	0	0	0	0	0	0	1946	1618	3564
Institutional	0	0	0	0	0	0	868	0	1715	2583
Industrial	7661	265	3173	0	11099	1308	7022	9323	9039	26692
Agriculture	0	0	0	0	0	0	1563	0	3860	5423
Transport	0	0	0	0	0	0	30632	0	0	30632
Total	111561	1553	15512	21866	150492	1360	44107	18736	26532	90683

Descriptions	Fuelwood	Charcoal	Agric Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial
Unit: MJ per Capita										
Domestic	4530	56	538	953	6077	2	175	326	449	950
- Rural	4868	57	549	996	6469	0	157	0	402	558
- Urban	2474	54	472	692	3692	0	290	2306	737	3332
Commercial	0	0	0	0	0	0	0	85	71	155
Institutional	0	0	0	0	0	0	38	0	75	113
Industrial	334	12	138	0	484	57	306	406	394	1164
Agriculture	0	0	0	0	0	0	. 68	0	168	236
Transport	0	0	0	0	0	0	1335	0	0	1335
Total	4864	68	676	953	6561	59	1923	817	1157	3954

Final Energy Consumption Pattern

Country Pakistan Region: Northern Mountains

Year: 1994/95

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Row-wise Percentage											
Domestic	64.5%	0.8%	7.7%	13.6%	86.5%	0.0%	2.5%	4.6%	6.4%	13.5%	100.0%
- Rural	69.3%	0.8%	7.8%	14.2%	92.1%	0.0%	2.2%	0.0%	5.7%	7.9%	100.0%
- Urban	35.2%	0.8%	6.7%	9.9%	52.6%	0.0%	4.1%	32.8%	10.5%	47.4%	100.0%
Commercial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	54.6%	45.4%	100.0%	100.0%
Institutional	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	33.6%	0.0%	66.4%	100.0%	100.0%
Industrial	20.3%	0.7%	8.4%	0.0%	29.4%	3.5%	18.6%	24.7%	23.9%	70.6%	100.0%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	28.8%	0.0%	71.2%	100.0%	100.0%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	100.0%	100.0%
Total	46.3%	0.6%	6.4%	9.1%	62.4%	0.6%	18.3%	7.8%	11.0%	37.6%	100.0%

Descriptions	Fuelwood	Charcoal	Agric. Residue	Animal Dung	Total Biomass	Coal/ Coke	Petroleum Fuels	Natural Gas	Electricity	Total Commercial	Total Energy
In Column-wise Percentage											
Domestic	93.1%	82.9%	79.5%	100.0%	92.6%	3.8%	9.1%	39.8%	38.8%	24.0%	66.8%
- Rural	86.0%	71.7%	69.7%	89.7%	84.7%	0.0%	7.0%	0.0%	29.8%	12.1%	57.4%
- Urban	7.2%	11.2%	9.8%	10.3%	7.9%	0.0%	2.1%	39.8%	9.0%	11.9%	9.4%
Commercial	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.4%	6.1%	3.9%	1.5%
Institutional	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	6.5%	2.8%	1.1%
Industrial	6.9%	17.1%	20.5%	0.0%	7.4%	96.2%	15.9%	49.8%	34.1%	29.4%	15.7%
Agriculture	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.5%	0.0%	14.5%	6.0%	2.2%
Transport	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	69.4%	0.0%	0.0%	33.8%	12.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

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A housewife cleaning an improved mud-built stove, Gorkha, Nepal
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Prepared by: K. Rijal

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Participating Countries of the Hindu Kush-Himalayan Region

- Afghanistan
- Bangladesh
- Bhutan
- China
- India
- Myanmar
- Nepal
- Pakistan

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