

An aerial photograph of a high-altitude mountain landscape. A vibrant turquoise lake is nestled in a deep, rugged valley, surrounded by steep, rocky slopes. The water's color suggests the presence of mineral deposits or glacial silt. The surrounding terrain is a mix of dark, craggy rock and patches of green vegetation. The lighting creates strong shadows, emphasizing the dramatic topography.

# Mountains of the World

Mountains, Energy, and Transport

Mountain Agenda



---

**Prepared for**

# **The UN Commission on Sustainable Development (CSD) and its 2001 Spring Session**

**Prepared by Mountain Agenda**

**Mountain Agenda** is an informal group of people with professional interests in sustainable mountain development, drawn from the academic and development cooperation communities. The group was created prior to the Rio Earth Summit (UN Conference on Environment and Development, 1992) to enhance the position of mountains on the global environmental agenda.

**Contact Address:**

Mountain Agenda

Centre for Development and Environment (CDE), Institute of Geography, University of Berne  
Hallerstrasse 12, CH-3012 Berne, Switzerland

Fax: +41 31 631 85 11

e-mail: [agenda@giub.unibe.ch](mailto:agenda@giub.unibe.ch)

© Mountain Agenda 2001

Printed by Buri Druck AG, Berne, Switzerland

On recycled environmentally friendly paper

ISBN 3-906151-55-7

**Prepared and published with the financial support of**

**SDC** Swiss Agency for Development and Cooperation



**Compiled and edited at**

**CDE** Centre for Development and Environment, Institute of Geography  
University of Berne



---

# Mountains, Energy, and Transport

|  |    |
|--|----|
| <b>Foreword</b>  | 3  |
| <b>Why focus on energy and transport in the mountains?</b>   | 4  |
| <b>Mountains and energy</b>  |    |
| • Mountains as global centres of hydropower  | 8  |
| • The future of the Icelandic Highlands: power plant or national park?   | 10 |
| • Hydropower and conflicts over water in Central Asia  | 12 |
| • Developing small-scale hydropower in Nepal   | 14 |
| • Solar energy in the Hindu Kush and Himalaya  | 16 |
| • Wind power in the mountains: examples from Switzerland and Norway  | 18 |
| • Sustainable fuelwood use in mountain areas   | 20 |
| • The cultural and spiritual dimensions of mountain energy   | 22 |
| • Human energy in the mountains  | 24 |
| <b>Mountains and transport</b>   |    |
| • Dilemmas of transport and energy development in Peru's Cordillera Carabaya   | 26 |
| • The challenges of Alpine transit traffic   | 28 |
| • Crossing the Atacama Desert: a link from the Pacific to the Atlantic   | 30 |
| • The Karakorum Highway: accelerating social and environmental change<br>in a formerly secluded high mountain region | 32 |
| • Access road construction in Ethiopia and Yemen   | 34 |
| • Human power instead of machines: rural access roads in West Flores, Indonesia                                      | 36 |
| • Bridges for rural access in the Himalaya   | 38 |
| • Ropeways for mountain tourism and development  | 40 |
| • Animal power: appropriate transport in mountain areas  | 42 |
| • Using communications technologies to promote access for mountain people  | 44 |
| <b>Mountain energy and transport:<br/>challenges for the 21st century</b>  | 46 |



# Foreword

Transport and energy are key factors in sustainable mountain development. In the case of Switzerland, they go back to the beginning of the country's history. Control of the Gotthard Pass, the most important Alpine transit route from Germany to Italy, was already an issue at this early date when income, Alpine trading rights, and resource use were at stake. The inhabitants of the Gotthard region at that time wanted the right of self-determination and the chance to make their own decisions about issues related to the pass. They did not want to be dependent on decisions made for them by people in the lowlands.

In those early days traders crossed the Gotthard on a trail with a so-called "elevated walkway" fixed against the rock wall that could be used to traverse the Schöllenen Gorge. This walkway was the most elaborate example of mountain infrastructure at the time. Later, infrastructure was gradually expanded in the form of a roadway across the pass. This route was first used by the Gotthard postal service with its horse-drawn coaches. Subsequent expansion permitted the first automobiles to cross the Gotthard, and today civil engineers have designed structures that support buses and lorries as well. Meanwhile, completion of the Gotthard tunnel in the late 19th century made it possible to cross the pass by rail. This was followed by a tube tunnel with two-way traffic for automobiles. Talk of building a second tunnel continues unabated.

All major mountain passes of the world have similar histories. In each case the issues concerned are: passage, transit, access, connections, integration of mountain regions with lowlands on each side of the pass, questions of political, economic and social development, and equitable balance between highland and lowland residents with respect to the use of mountain resources. This calls for a careful consideration of multiple interests and processes of negotiation to strike a balance.

The positive aspects of mountain development include jobs, openness to the outside world, exchange, and economic development. The negative aspects are one-sided resource use, political dependency, heavier-than-average traffic and resultant pollution, and serious environmental hazards. Nor should the question of costs be overlooked. What is the price of transport through mountain regions? Who should bear its considerable costs? How should these costs be distributed equitably and realis-

tically among different interest groups and beneficiaries?

Traditionally, the advantages of mountain development have largely accrued to the lowlands, while the disadvantages have generally been felt by residents of the mountains. Similar examples could also be cited in the area of energy production and use of other mountain resources.

The present document will examine transport and energy in the mountains and related questions. In accordance with what has now become a tradition in these reports, we shall focus first on the most significant issues surrounding transport and energy in relation to sustainable mountain development. These issues will then be illustrated by means of specific case studies, concrete experience, and best and worst practices around the world. The final chapter will deal with the elements and issues that are most important for future strategies, and address the question of implementing these strategies among various target groups. In this sense the report will contribute to better understanding of and support for sustainable mountain development in the energy and transport sectors.

That the issues of mountain development are as current and as controversial today as they were when Switzerland was first founded – bringing us back to our starting point – is illustrated by the lengthy discussions and difficult negotiations in recent years between Switzerland and the European Union on the issue of transit through the Alps. The challenge today is still to negotiate an equitable balance between the interests of the various partners.

It is important that knowledge, experience, commitment and political will be brought to bear on sustainable mountain development in order to ensure positive forms of development that benefit everyone. This report is intended as a contribution to discussions for this purpose.



Walter Fust

Director, Swiss Agency  
for Development and Cooperation

Frontispiece:  
Chinese ink drawing  
dating from 250 BC, showing  
a simple ropeway  
system for crossing steep,  
narrow valleys. The system  
is still used today in the  
mountains of southern  
China. The search for technologies  
to deal with the challenges of mountain  
environments is as old as  
humankind.  
(Courtesy H. D. Schmoll)



Inside a tourist lodge, Nepal. Fuelwood is the dominant form of energy in many mountain areas worldwide. (M. Jampen)

The reservoirs of Lake Oberaar and Lake Grimsel, Swiss Alps. Here, as in mountain regions generally, hydropower is generated mainly to serve the needs of downstream areas. (H. J. Zumbühl)

*"Historically, questions about dams were limited to where to build them and how big they should be. What we have learned over the past decades, however, is that we should have been asking a far wider range of questions related to their economic and social costs and their environmental and ecological impacts". (The World's Waters 2000–2001:114)*

*"If we have electricity, we women can do many things in the evening... some bought grain mills but we have no power and cannot use them... [without power] the lamp is not lit, the mill machine cannot be used." Wa woman farmer, Yunnan, China*

## Why focus on energy and transport in the mountains?

Energy and transport are key issues in sustainable development. Both are essential for the sustainable development of mountain areas, a topic of increasing concern recognised in Chapter 13 – "Managing Fragile Ecosystems: Sustainable Mountain Development" – of Agenda 21 and more recently by the declaration of the International Year of Mountains in 2002. Yet energy and transport in mountain regions also involve vital linkages between these regions and adjacent lowlands and urban areas.

Energy from the mountains comes in many forms which have been essential for economic development in adjacent regions: most important have been hydroelectricity and wood. Yet mountain people often gain little from large-scale energy developments, have received little compensation for the use of their resources, and have been sidelined by national energy policies. While mountains have long been seen as obstacles to movement, transport networks are essential for providing access to mountain resources and opportunities to develop tourism, and for allowing mountain people to get to markets and jobs outside the mountains.



### Mountain energy sources

The marked altitudinal gradients of mountains means that they have huge potential for the production of energy, particularly hydroelectricity. Mountain people have long used water power at small scales, especially for milling. Within the mountains, water power was used in early industrial developments, usu-

ally based on local natural resources such as wood and minerals, and has been important in developing textile industries in certain mountain areas. Yet the main energy source for most mountain people remains wood – a resource that is becoming scarcer in many developing countries. This scarcity leads to severe environmental and socio-economic impacts.



Modern technologies can be used to increase the efficiency of fuelwood and other biomass fuels, but their introduction must be sensitive to local conditions and be properly resourced. This also applies to other renewable energies, such as solar and wind power, which have great potential in mountain areas. Certain mountain areas also have considerable geothermal energy potential.

**Small hydroelectric schemes are highly efficient in serving local energy needs in mountain areas. See pages 14–15**

### Benefits from energy

Energy is essential for life, particularly for cooking, but especially for heating in mountain areas. Local energy sources are also important for artisans and small-scale industries, and hence for employment and income; mountain people worldwide are well-recognised for the quality of their products. Modern technologies based on solar and wind power can provide additional income opportunities, decrease health risks, and generate electricity for lighting and communications.

Decentralised production of energy is particularly appropriate in mountains, due to the distance between settlements and the high costs of constructing and maintaining distribution networks. Yet the greatest benefits of energy derived from mountain areas often accrue to people in the lowlands through the export of electricity, wood, and charcoal.

**Simple devices can double or triple the efficiency of fuelwood use. See pages 20–21**

### Negative effects of energy use

While wood and other biomass fuels are the principal energy sources for mountain people, inefficient combustion has serious effects on their health – especially the health of women, the primary users of domestic energy. Where demands for fuelwood are high, harvesting may cause severe damage to forests. When fuelwood supplies are inadequate, manure and other biomass may be used as sources of energy, rather than for fertilising fields and improving soil structure. In some cases, damage to forests may influence slope



### Mountain hydropower produced for downstream areas

Typically, mountain regions produce much more hydropower than they use themselves. In the late 1990s, the State of Grisons in the Swiss Alps produced 7500 GWh of hydroelectricity per year. Of this, 1680 GWh (23%) was used locally, while 5820 GWh (77%) was exported to downstream urban areas and industrial centres. (Swiss Federal Office for Water and Geology)

stability, increasing the likelihood of natural hazards such as landslides and avalanches. The availability of agricultural and forest land can also be threatened by the construction of hydropower dams in mountain areas, which flood land that is valuable not only for human livelihood but also as a scarce habitat for wild plant and animal species. At a larger scale, pollution from lowland power plants burning fossil fuels often has serious impacts on mountain ecosystems, leading to the decline and even the death of forests.

Difficult road conditions in northern Pakistan. Roads have been the most important means of improving access to mountain areas in recent decades. (U. Lutz)

*“In mountain regions, renewable energy technologies such as small hydro, solar, wind, biomass and fuel cell, are often cost effective from the beginning. It is possible to attain a high degree of sustainability and self-reliance even in remote areas, provided that there is access to technology, knowledge, and capital”.*  
Energy expert and member of parliament, Switzerland

### Mountain areas: the world's powerhouse for renewable energy

Hydropower provides more than 97% of all electricity generated worldwide by new renewable sources (i.e. solar, wind, geothermal, biomass). Mountains generate a substantial portion of this hydropower. They thus play a crucial role in helping move the world away from its present unsustainable form of energy use based on fossil fuels, a major cause of global warming. However, future hydropower developments must take into consideration the lessons learned regarding the negative social and environmental impacts of large dams.

Freight train hauling cars across the Swiss Alps. Railways heralded the age of mass transport in mountain regions in the late 19th century. (SBB/A. Boillat)



*“Since road transport has been available, people go to better-developed areas, earn money, and come back and build here.”*  
Ethiopian priest/farmer

Copper mine in northern Chile. Improving transport infrastructure in mountains and upland areas can increase the pressure on natural resources such as water and clean air. (B. Jenny)

### Transport in the mountains

Mountains often present major barriers to communication for those who live in adjacent lowland areas. Yet people have always developed trails through mountains for themselves and their pack animals. Since the mid-19th century, road and rail networks into and through mountain areas have expanded for two main reasons: economic development and military strategy, which are often linked. High-capacity infrastructure is linked to lower-capacity feeder networks that have improved access for people and made it easier to transport raw materials and goods. More recently, tunnels have removed many of the dangers of travel in certain mountain areas. Also, new communications technologies are beginning to make the constraints of mountain topography less relevant.

Labour-intensive road construction leaves as much as 30–40% of total investments in mountain areas – in the form of wages paid for local labour. There are other benefits as well – see pages 34–37

### Benefits of transport networks

Transport infrastructure is essential for all mountain economies: even the most remote villages have always relied on traders for salt



## Mobility in the mountains: a powerful agent of change requiring careful management

Modern technologies are gradually removing the challenges of access to even the most remote mountain areas. As access and transit in mountains have largely been driven by downstream political and economic interests, mountain areas are being drawn into regional and continental transport networks in an increasingly mobile and globalised world. Access is a very powerful agent of change. Change needs to be managed with the active support of mountain communities, with a view to reducing upstream-downstream inequities and compensating mountain regions for transport services required by contemporary societies.



and other valuable goods. Within the mountains, increasingly sophisticated technologies – bridges, roads, railways, tunnels – are gradually removing many of the challenges of access. Transport networks make it possible for mountain people to travel to other parts of their own mountain regions and to adjacent lowland areas to study, sell their goods, and look for employment.

These networks are also vital for the spread of ideas and innovations and the development of tourism. However, the sophistication and density of these networks varies greatly at every scale, both within and between mountain regions, depending particularly on the financial resources that are available.

**Ropeways (cableways) are often the most appropriate and cost-effective means of transport in mountains. They are also one of the safest. See pages 40–41**

### Negative effects of transport networks

The construction of even the simplest transport network in a mountain area is expensive. Road and railway construction can have severe impacts on slope stability and ecosystems if inappropriate methodologies are used. Vegetative cover, preferably with local species, is essential to stabilise steep slopes.

Once constructed, transport infrastructure requires higher levels of maintenance than in lowland areas because of the steep slopes and more frequent natural hazards, such as landslides and avalanches. High traffic levels can lead to severe pollution, with negative impacts on the health of both people and forests. For mountain people, the development of transport infrastructure often leads to emigration, especially of younger people, in search of better-paid and more pleasant jobs. The introduction of new ideas and attitudes can disrupt mountain cultures.

### Key issues addressed in this report

The development of energy and transport infrastructure in mountain areas requires that a number of issues related to sustainability be addressed, including:

- how can demands from lowland and urban areas be balanced with the needs and demands of mountain people?



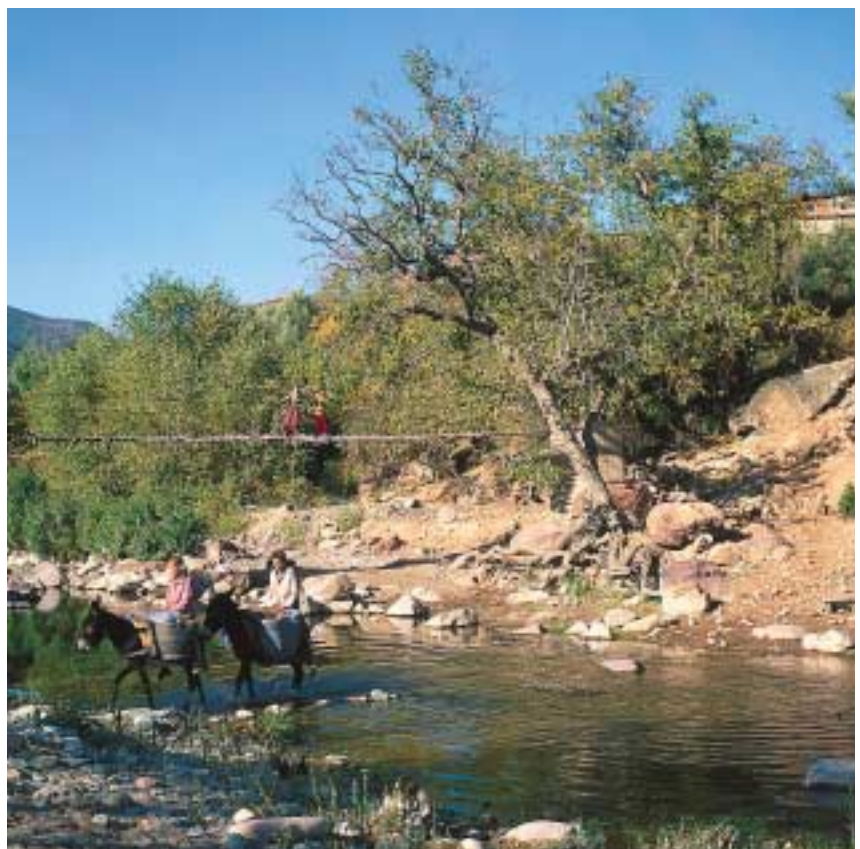
- how can mountain people be compensated for the benefits they provide to society as a whole?
- what new technologies can be used to maximise benefits to both mountain people and those in the lowlands?
- how can mountain people participate equitably in decisions regarding energy and transport?

The present report addresses these key questions by documenting local and regional experiences from different parts of the world. It concludes by presenting opportunities for the sustainable development of both energy and transport in mountain regions, with concrete suggestions and recommendations addressed to different stakeholders.

Trans-national gas pipeline in the Caucasus, Georgia. Rehabilitation of the fragile vegetation cover is a great challenge in the development of transport facilities in mountains. (H. Meessen)

*“Before the road was built, it took me two days to carry heavy sacks of rice out and heavy sacks of fertiliser back in”.  
Nepalese farmer*

Suspended bridge and animals – two widely used means of solving transport problems in mountain regions worldwide. From the Atlas Mountains, Morocco. (D. Maselli)

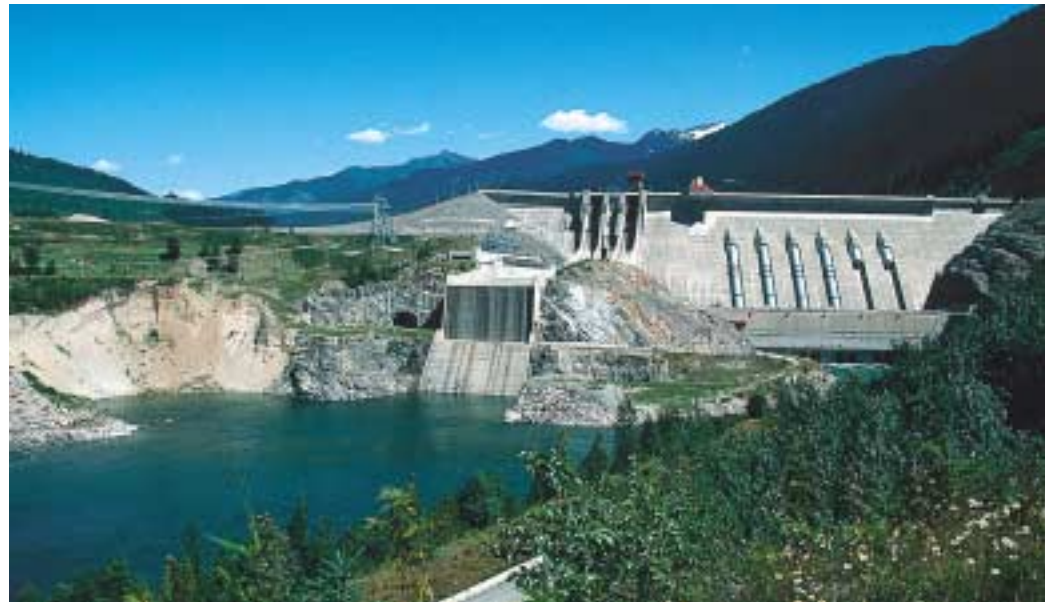


# Mountains and energy

## Mountains as global centres of hydropower

Hydropower provides 19% of the world's total electricity supply. Over 150 countries use hydropower, and a third rely on it for more than half of their electricity needs. While industrialised countries have developed most of their potential hydropower sites, most developing countries have tapped little of their potential. The substantial hydropower potential of mountain areas derives from their high gradients, relatively high precipitation and runoff, and storage of water as snow and ice. Gorges allow the storage of large amounts of water in deep reservoirs behind dams with relatively modest construction, and without inundating a large area. Stored water is often used for irrigation and urban water supply as well as for generating electricity.

Revelstoke dam on the Columbia River, Canada. Canada is the largest producer of hydropower in the world. With 13 dams, the Columbia River Basin is among the basins most significantly altered by large dams worldwide. (H. P. Liniger)



Installation work on the electricity supply line in Salleri, Nepal. Small hydropower schemes such as the one in Salleri have a substantial potential to support economic development and self-reliance in mountain areas, without disrupting local culture and the environment. (ITECO)



### Energy for the mountains

Hydropower often provides the most accessible and cheapest option for mechanical power and electricity in mountain communities. Many mountain areas in developing countries have a very long tradition of using vertical axis water mills to turn millstones; 200,000 such mills are still operational in the Hindu Kush and the Himalaya. Here, more sophisticated turbines are being installed to produce electricity from small streams to meet local needs.

In many rural mountain communities around the world, small hydropower stations have provided the first source of power and the basis of electrification. Extending central power grids to scattered mountain communities is an expensive way to provide electricity when demand is

low. Where the resources exist, isolated hydropower mini-grids are often the best option. The main challenge in making them

In China, a third of the counties and 40% of rural townships rely on small hydropower for most of their electricity. In Nepal, 1500 hydropower turbines provide milling services to 2 million people – 10% of the population – and 800 plants of various sizes supply electricity to half a million people not connected to the national grid.



economically viable is to increase the use of power during non-lighting hours. In run-of-river projects (projects without storage structures), electricity can be generated 24 hours a day at no additional cost. Most isolated power plants are, however, only loaded for 4–6 hours a day for evening lighting and television. Promoting organisations encourage communities to use electricity during off-peak hours, the main goals being to reduce unsustainable rates of firewood consumption and create non-farm jobs for people within their own communities.

Experience suggests that electricity cannot by itself create new economic sectors but can add value to existing ones; it can create jobs and be used for cooking. In Nepal, the best opportunities for electrically powered productive applications exist in areas with agricultural surpluses that are linked to transportation networks, and in trekking destinations with a strong local

**Norway has developed 65% of its hydropower potential. Nepal and Ethiopia have developed less than 1% of theirs.**

economy. Electric cooking has been most successful in tourist areas where labour to collect firewood is expensive and limited, and where firewood collection is restricted because of national park or conservation regulations, as in the Sagarmatha (Everest) National Park.

### Energy for export

Energy from larger dams and power stations is often exported from mountain areas. While most dams are in the mountains, most of the services they provide – irrigation, flood control, navigation, and electricity – are used in the more densely populated plains and nearby urban areas. Mountain areas in developing countries receive little compensation for providing these services but are subject to negative environmental and social impacts.

In 2000, the World Commission on Dams (WCD) noted that, while the benefits derived from larger dams have been considerable, in too many cases an unacceptable and often unnecessary price has been paid, especially in social and environmental terms. Dam building institutions and agencies have not adequately involved the people affected in decisions to build a dam. Nor have they transferred sufficient resources from the beneficiaries to those affected. The WCD has put forward a 'rights and risks' approach to dam building which proposes that "those groups



facing the greatest risk from the development have the greatest stake in the decisions and, therefore, must have a corresponding place at the negotiating table."

Many countries charge developers a royalty for the use of hydropower sites, particularly for larger projects that export energy outside the region. Few developing countries have provisions for sharing this income with affected communities: an important step in compensating them for the use of their resources. Under a 1916 law, communities in Switzerland are entitled to considerable annual payments and quotas of free energy for granting the rights to hydropower development on their territory. Brazil has a 1989 law which requires that, of the royalties paid for using water for power generation, 45% goes to the municipal districts affected by the venture, another 45% goes to the state(s) where the venture is located and only 10% goes to the federal government. Even though money available to local government may not necessarily always be spent in the interests of the affected communities, this is a good start. Certainly some of this money will be used to provide energy services to the mountain communities themselves.

*Bikash Pandey*

Wooden runner of traditional water mill in operation. Hydropower often provides the most accessible and cheapest option for mechanical power and electricity in mountain communities. Many mountain areas have a very long tradition of using water mills for grinding grain. In Nepal, initiatives have been launched for upgrading traditional mills to generate more power for milling and for production of cheap electricity. (ITDG Photo Library)

*In urbanised and densely populated downstream areas, the costs of grid connection are roughly equal to the costs of electricity generation. In mountain areas with difficult topography and dispersed settlement, the costs of grid connection can be two to five times as high as the costs of electricity generation when electricity is produced in large, centralised power plants.*  
(R. Rechsteiner)

Nam Hinboun River, Laos. To generate electricity mainly for export, Laos plans to build about 40 new large dams – a plan that will disrupt the livelihoods of thousands of local residents. At present, the country has 4 large dams. (T. Kohler)







Dettifoss in northeastern Iceland, one of the largest and most powerful waterfalls in Europe. Iceland has abundant water resources, of which less than 10% are harnessed. Dettifoss would not be affected by proposed hydropower schemes. (G. I. Eggertsson)

## The future of the Icelandic Highlands: power plant or national park?

Icelanders are facing their greatest environmental controversy, with heated disputes over plans to dam rivers northeast of Vatnajökull, the country's largest glacier. The government sees this as necessary for the region's economic development. Environmentalists believe this development will have negative impacts on this area of high conservation value. They have offered an alternative vision of development by proposing the creation of Europe's largest national park.



### Current plans

Iceland's National Power Company plans to build a 650–700 MW hydroelectric power plant – the largest in Iceland, and one of Europe's largest – and sell the energy to a proposed aluminium smelter. Two large glacial rivers would be dammed, with smaller dams constructed in nearby rivers. By law, both the power plant and the aluminium smelter must undergo an environmental impact assessment (EIA) process, to be concluded by February

2002. The Minister of Environment has also agreed to establish a working group to evaluate the conservation value of the land north of Vatnajökull, to report at the same time.

### The Icelandic Highlands

The Icelandic Highlands are unique, characterised by vegetation-free mountains, glaciers, lava, and black sands. As the country's 270,000 inhabitants live close to the coast, the highlands are largely untouched.

Hydropower provides Icelanders with most of their electricity, but only a small fraction of the potential is used. Existing dams are mostly in southern Iceland, close to the metropolitan area, and in the north. The rivers northeast of Vatnajökull represent about 15% of the unused potential for hydropower.

### Economic interests

Iceland's economy is still largely based on fisheries, which provide up to 50% of export revenue. The collapse of the Atlantic herring stock in the late 1960s crystallised the need

### Hydropower potential in Iceland

|                             |                            |
|-----------------------------|----------------------------|
| Technically possible:       | 64,000 GWh                 |
| Economically feasible:      | 40,000 GWh                 |
| Environmentally acceptable: | studies currently underway |
| Harnessed (by 1999):        | 4000 GWh                   |

*Source: Icelandic Energy Institute*

to diversify the economy by capitalising on Iceland's other major natural resource: renewable energy, from hydropower and geothermal heat. Government policy has been to utilise this energy for large-scale industries, especially aluminium smelters. The government has created an attractive environment for foreign investors, offering favourable prices for electricity.

The hydropower schemes are not only central to the government's policy of diversifying the economy, but also fit into its rural development policy. Many rural areas, including eastern Iceland, have been experiencing a declining economy and depopulation. Thus, many rural areas are pressing the government to foster economic growth.

### Conflicting views

The National Power Company began exploring options for damming the glacial rivers northeast of Vatnajökull decades ago. The authorities gave permission to build projects, but these were called off or delayed for various reasons. In 1998, when the government began negotiating with foreign investors about building an aluminium smelter, loud opposition to the project developed.



The original plan was to build a 210 MW power station which would have been exempt from EIA since the operating licence had been granted in 1991, three years before laws about EIA came into force. The project would have meant that a wetland with important habitats would have been submerged. Environmental non-governmental organisations strongly opposed this project, but the exemption of the power plant from the EIA process caused even more controversy. Eventually, the investors decided it would be more profitable to build a larger smelter. This required a larger power station, so the National Power Company had to look for another option and chose to focus on existing plans for a 650-700 MW station. This meant the project, which would almost double Iceland's electricity production, had to undergo a formal EIA process.



The local authorities in eastern Iceland strongly support these plans, but environmentalists continue to lobby against the project, emphasising the area's conservation value. The parliament has agreed to establish a national park including the whole Vatnajökull glacier in 2002, but environmentalists argue this should be much larger: 20,000 km<sup>2</sup>, including the area northeast of the glacier. They point to the increasing importance of tourism, which recently replaced large-scale industries as the second most important source of foreign revenue after the fishing industry. Many tourists come to Iceland because it is one of the few western European countries with large wilderness areas. Thus, the national park could be a better development option since it would strengthen Iceland image as a natural sanctuary, with a positive impact on the tourist industry.

The end results are far from certain. The final decision will depend on the results of the EIA. Yet it is clear that lively debate will continue until the matter is settled.

*Audur H. Ingólfssdóttir*

Mt. Snæfell in the highlands northeast of Vatnajökull Glacier, located in the area that would be affected by proposed hydropower schemes.  
(G. I. Eggertsson)

Aluminium smelter at Straumsvík, Iceland. The smelter was built in the 1960s in a bid to diversify Iceland's economy. Aluminium production is power-intensive; the smelter at Straumsvík consumes more electricity than the country's capital, Reykjavík, with over 130,000 inhabitants.  
(ISAL/H. Petursson)

**The proposed hydropower scheme will clearly bring some economic benefits to the region. It is equally clear that the project will greatly affect the environment. The fundamental question raised is if the economic goals of the region could be met without the environmental sacrifices.**

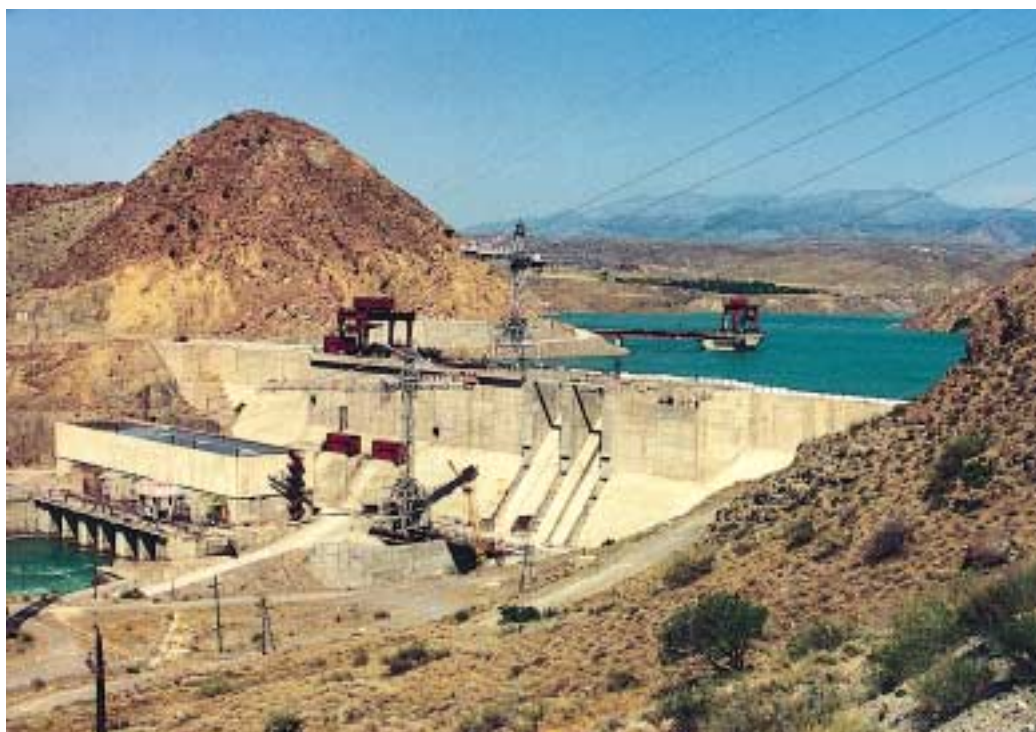




## Hydropower and conflicts over water in Central Asia

The Syr Darya River rises in the Tien Shan Mountains and flows to the Aral Sea through the present-day states of Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan. The area has a history of 4000 years of irrigation-based agriculture. In the 1920s, the Soviet government started to centralise the water allocation system, taking it out of the hands of the traditional water masters, elders, and councils. Traditional small-scale irrigation systems were transformed to large systems for cotton production. From the 1940s, the government began to tap an additional potential of the Syr Darya's water: hydropower. Dams have since been constructed or are under construction on various parts of the river and its main tributary, the Naryn. Today, the challenge of reconciling needs for water in this complex region is immense.

Reservoir, dam and hydro-power station at Tash Kumyr in Kyrgyzstan. This facility, which has an estimated capacity of 450 MW, belongs to the Naryn/Syr Darya Cascade System. (H. Hurni)



### A desert lake results from policy failures

Uncoordinated water use in the Syr Darya Basin has resulted in the formation of an unwanted body of water in a desert landscape: Lake Arnasai. The size of the lake is increasing steadily. With its current maximum surface area of 33,000 km<sup>2</sup> it covers an area larger than Belgium.

The boundaries of the nations formed after the disintegration of the Soviet Union are based on former Soviet administrative units, not on geographical realities. In the Syr Darya Basin, these boundaries cut across a large integrated water management system. The rivers now cross national borders several times, and storage reservoirs are located close to national boundaries. This makes the control of water resources on the territory of individual states very difficult, especially because models of water utilisation are contradictory, requiring water supplies for both hydropower and irrigation. Sharing water resources between the states during the process of



nation-building is a very delicate political task complicated by deteriorating economies, high rates of unemployment, rapid population growth, and the highly complex ethnic situation.

### Upstream-downstream tensions

Although mountains occupy only 38% of the basin of the Syr Darya, they supply 95% of the water that flows down the river. In the natural cycle, water is stored in the mountains during the winter, and released as meltwater in the summer, the critical season for irrigation. However, the Naryn/Syr Darya Cascade System, constructed since the 1940s to regulate water flows and generate electricity, has greatly changed this pattern. For Kyrgyzstan, economic imperatives mean that hydropower is generated in winter. At this time of year, the valleys in the downstream parts of the river in Kazakhstan and Uzbekistan are frozen. The solution has been to dump the excess water into a natural basin in the desert, creating the new Arnasai Lake, which has grown to an area of 33,000 km<sup>2</sup> since 1992. For Uzbekistan and Kazakhstan, where water has traditionally been used in summer for irrigation, this has caused serious problems for agriculture, as well as severe environmental problems, due to the loss of a huge amount of water through evaporation and infiltration, and an increase in groundwater levels. This is one of the causes of the shrinkage of the Aral Sea.

### Politics and the lack of reliable data

These problems are well known and are often discussed during meetings between the states. The governments as well as water management authorities and hydrometeorological surveys mistrust each other's hydrological measurements; values often vary by 50–100%. The differences can partially be explained by politics, but also result from the economic situation; the hydrometeorological survey system is becoming obsolete, as hydrological and meteorological stations cannot be maintained, and salaries for personnel cannot be paid. Consequently, there are almost no measurements of water flow at the reservoirs, or of water distribution into the canal systems or rivers. Large international projects are being developed to improve this situation. However, an independent source of information, such as satellite remote sensing, is urgently needed in order to ensure the support of the representatives of all countries involved, and to find common ground to solve the regionally very important economic and political tensions. Once agreement can



be reached on quantities of water, further solutions will have to be developed with regard to its allocation.

### Elements of integrated regional water management

In the agricultural sector, the efficiency of water use, particularly through the cultivation of water-saving crops, needs to be improved, and locally-adapted conflict management structures developed, using models similar to those that existed before the socialist era. These structures would have to be supported by national laws and regional agreements as well as economic measures, such as differential water tariffs with different prices for agriculture, industry, fishing, domestic use, and hydropower. External and internal costs such as administrative costs, costs for water protection measures, reconstruction and maintenance of dams and canals would have to be covered by an appropriate pricing policy.

*Michael F. Baumgartner, Manfred Spreafico,  
Heinz W. Weiss*

Irrigation of rice in Uzbekistan. If agricultural production were shifted towards crops that require less water than rice, the pressure on scarce water resources could be reduced significantly.  
(MFB-GeoConsulting)

### Central Asia's water dilemma

Although mountains occupy only 38% of the Syr Darya Basin, they supply 95% of the water that flows down the river. This water is crucial for hydropower generation, domestic supply, and irrigation in this mostly dry region. The countries that share the Basin face a major political challenge: how can they achieve equitable distribution of water against the background of conflicting water demands, ailing economies, and decaying water infrastructure?



## Developing small-scale hydropower in Nepal

Mountain people are often disadvantaged by being cut off from transportation and communication. Yet there is often great potential for the development of decentralised hydropower to stimulate sustainable local development. In Nepal, 80% of the population lives in rural areas, adding an important political dimension to decentralised electrification. Nepal's installed electric generating capacity is around 390 megawatts (MW), of which about 85% is hydroelectric and the remainder diesel power. There are frequent power outages, and only 15% of the population has access to electricity. Only 1% of the economically feasible hydroelectric potential, estimated at 44,000 MW, is currently exploited. Potentially, Nepal could supply both its rural and urban needs and even be a large power producer and an exporter to neighbouring countries.



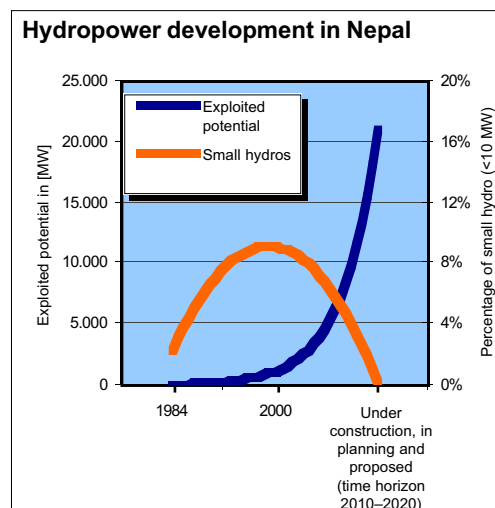
Salleri in 1992 (left) and 2000 (right). The village is no longer at the end of the world. Migration and brain drain to urban centres has stopped. As Salleri still lacks an access road, the small power plant did not result in large-scale industrial development but in the promotion of small, thriving enterprises. (ITECO)

Nepal's ambitious plans for electricity generation rely on large-scale hydropower schemes to serve the needs of foreign electricity markets and urban centres – a policy which will strongly disadvantage mountain areas: while small decentralised schemes currently account for 9% of total capacity, this proportion is expected to drop to only 0.1% in future. (Source: ITECO)

### The economics of rural electrification

Least-cost power generation schemes, streamlined for production economics, are often very large. Their production is geared to earning foreign exchange in distant industrial centres and neighbouring countries. Rural electrification is, if at all, of marginal concern. If profits are the main consideration,

economies of scale never favour small schemes. Scaling down hydropower units from 10 to 1 MW increases specific costs of installed capacity by 40%, and scaling down from 1 MW to 100 kW by another 70%. However, for remote areas far from the national grid, isolated power utilities have a competitive edge. Harnessing water power is by far the best choice, leaving photovoltaic schemes – whose production prices are five times higher at present levels – far behind.



### The Salleri Chialsa small hydro project

Salleri is the district headquarters of Solu Khumbu, 80 km south of Mount Everest. On foot, the nearest road head is three days distant, over high mountain passes, and the nearest airfield is an hour away. Fourteen years ago, the first electric bulbs were switched on, fed by a 400 kilowatt (kW) small hydro plant on a small mountain stream below Salleri. Today, the Salleri Chialsa Electricity Company Ltd. (SCECO) is fully autonomous. The power utility operates two crossflow turbines and an isolated grid, providing electricity to 900 commercial and domestic consumers. With a 98% grid

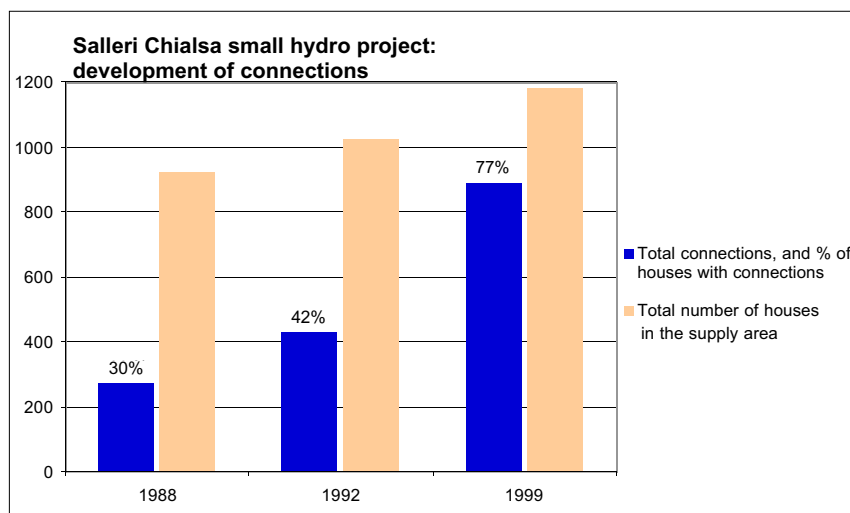


availability\*, reliability is second to none. Small business and cottage industries now provide quality employment opportunities and income to a well-educated new middle class.

The Salleri Chialsa Project was initially supported by a Swiss government agency, which commissioned the design and construction of the plant and grid. An extensive training component was included with a technical assistance package, ensuring know-how transfer in all relevant technical, organisational, and financial aspects. Long before the current trend of privatisation of infrastructure utilities, SCECO was designed as a private shareholder company, including local consumers as shareholders. Its financial condition is sound and stable, with a remarkable sum set aside for depreciation. The coming challenge is to develop and manage local telecom and television systems. SCECO envisages the construction of a second small hydro plant, to meet rising demand in the service area.

### Distributing the benefits of hydropower

In coming decades, Nepal's power sector is expected to boom tremendously. Hydropower projects currently under construction, planned, and proposed should boost the country's total generating capacity by a factor of 65, to 22,000 MW, half of the country's economic hydropower potential. The government's tax and duty concessions plus a commitment to purchase generated power strongly encourage private investment in the hydropower sector. Losers in this rapid development will be the country's remote areas



served by decentralised small hydro schemes, as independent power producers will invest mainly in large, least-cost schemes, connected to the national grid's high tension backbone. While small hydropower schemes (less than 10 MW rated capacity) currently account for 9% of Nepal's hydropower capacity, only 0.1% of upcoming capacity will be generated in small hydro schemes. However, as the Salleri Chialsa example shows, electricity can trigger modest but sustainable development in remote areas, benefiting a large portion of the population. Yet without initial external support, the scheme would never have taken off. Such support from concerned governments and donors is crucial to ensure well-balanced decentralised development.

*Christoph Mor, Walter Zimmermann*

Initially designed to combat rapid deforestation by replacing fuelwood with electric power for wool dyeing in a local factory, the power plant now supplies energy to 900 commercial and domestic consumers.

(Source: ITECO)



Second-best equipment is very often not good enough for small schemes. Technically sound design and appropriate, high-quality machinery ensure high production efficiency and considerably reduce operation and maintenance costs. (ITECO)

*\*98% grid availability means that electricity is available on 358 days per year, i.e. 98% of 365 days.*



## Solar energy in the Hindu Kush and Himalaya

The abundance of solar energy in the Hindu Kush and Himalaya has prompted many solar energy programmes. However, they have not yet resulted in any significant use of solar energy, mainly due to the lack of affordable technical solutions and adequate institutional mechanisms to ensure energy resources are matched with needs, to the inadequate appreciation of socio-economic and cultural factors, and the failure to fully understand the spatial characteristics of the mountains. Nor has the allocation of financial resources for developing solar energy in the mountains received priority on national agendas.

Women using a solar cooker to prepare food. Women should actively participate in designing and implementing programmes for solar power development, as they are often the primary users.  
(K. Rijal)



Map showing the availability of solar radiation for solar power generation in the Hindu Kush and Himalaya. Regions north of the main range of the Himalaya have the highest availability due to high altitude and reduced cloud cover during the monsoon season.  
(Source: ICIMOD, K. Rijal)

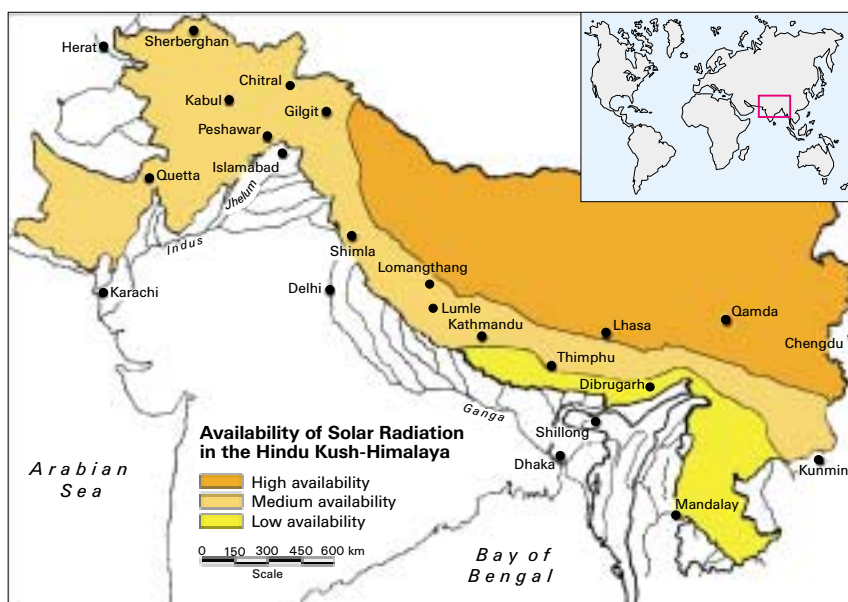
### The potential of solar energy

Regions with dry climates within 35° of the equator are particularly suitable for the utilisation of solar energy, since there is more diffuse

radiation than at higher latitudes, and less cloud cover. In addition, snow peaks act as large reflectors to raise the albedo, locally increasing the amount of radiation. Relief, altitude, slope, and aspect significantly influence the availability of solar energy in mountain areas and thus require proper understanding.

Across the region, there is a large difference in solar radiation in December and January, due to prolonged foggy mornings in some valleys. Variation in summer (June–August) is due to difference in cloud cover. Radiation is higher in places such as Lhasa and Chitral because of low rainfall, and low in places like Lumle in Nepal, which experiences heavy rainfall during the monsoon season. The lowest variation across the region is in April, when the sky is clearest.

The overall amount of energy required in mountains is generally quite low due to the scattered settlement pattern and lack of infrastructure development. Energy potential in the mountains is also extremely scale-sensitive. Thus, decentralised renewable energy systems based on solar, water, and wind energy are par-



ticularly appropriate. Small-scale interventions in mountain communities also entail less risk than large-scale interventions.

There are many options for the use of solar energy. Solar cookers are widely used in the mountain areas of China and India, and there have been initiatives to promote them in Nepal and Pakistan. Space heating, using passive solar building technologies, has been incorporated in the retrofitting of buildings in Tibet and in Ladakh in India. Lighting with solar home systems and lanterns has been successful in many areas, but centralised systems failed in Nepal and Pakistan. Solar power also has great potential for telecommunications, television, radio, and computer operation; almost all remote airport and telecommunication facilities in Nepal are powered by solar energy. However, there is still a huge potential for the use of solar energy in the region.

### Facilitating the adoption of solar photovoltaic (SPV) systems

The attractions of photovoltaic arrays include lack of moving parts, very slow degradation of properly sealed cells, the possibility of modular systems of various sizes, and extreme simplicity in use. While SPV systems still cost five times more than conventional sources of energy production, they can serve a 'niche' market for isolated and remote mountain areas with no feasible options for lighting, communications, or computers. Such facilities not only improve the quality of life of mountain people but also provide opportunities for them to diversify income-generating activities, to reduce health hazards and, for children, to study more.

Various key factors must be considered when formulating policies and actions for the adoption of SPV systems. Subsidies and incentives should primarily be based on economic and social equity analyses; often, most owners of solar home systems belong to high-income groups. Properly designed subsidy programmes and full-cost recovery-based financial operation of SPV programmes are the minimum prerequisites for financial sustainability. In this context, access to financial resources must be transparent and flexible enough to facilitate access by poor and marginalised people. Women should actively participate in designing and implementing SPV programmes, as they are the primary users; promotional activities have generally not recognised the socio-cultural implications of technology adaptation. Commercialisation also has to be developed, with governments creating the right kind of policy atmosphere

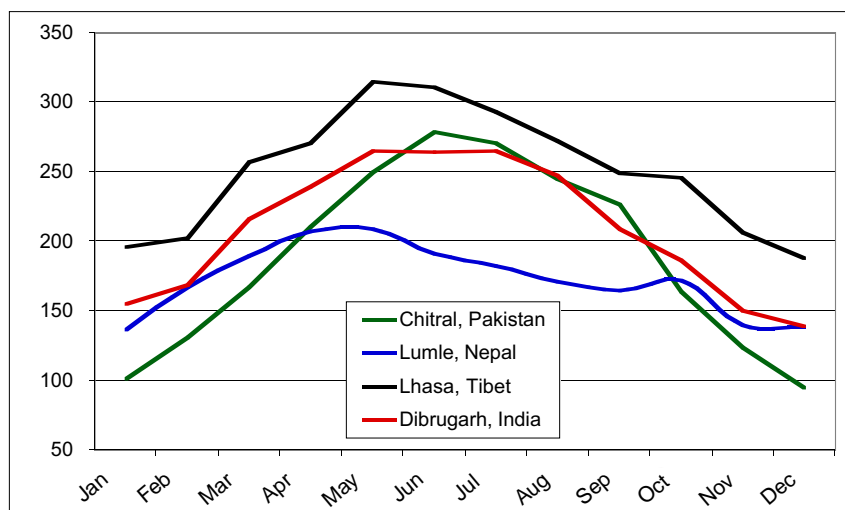


to attract investments from entrepreneurs, and facilitating effective schemes for standards, warranties, and insurance.

A key need is coordination between various donor agencies and government institutions, to avoid duplication of effort. Donors may be interested in capacity building, marketing technologies, research and development, or promoting SPV technologies in specific areas or to specific ethnic groups. Each should be allowed to function with clear mandates and objectives. The lessons learned and successful strategies in disseminating SPV systems must be taken into consideration while designing future programmes.

Solar water heater installed on the rooftop of a tourist lodge. Solar water heaters, a cheap and low-maintenance device, can help reduce high fuelwood consumption rates in tourist areas.  
(K. Rijal)

*Kamal Rijal*



Monthly averages of daily global solar radiation in specific areas of the Hindu Kush and Himalaya. Regional variations are highest in the monsoon season (May–September), when regions in the rain shadow (Lhasa, Tibet) have much higher radiation due to low cloud cover than lowland areas, which are fully exposed to the monsoon rains (Lumle, Nepal). Figures in Watt/m<sup>2</sup>. (Source: ICIMOD, K. Rijal)





Wind measurement equipment (anemometer) used for steering the rotor blades of a wind power plant. In mountain areas icing can occur; under such conditions, heated wind measuring equipment is necessary to ensure proper functioning of the power plant. (R. Horbaty)

150 kW wind turbine in the Jura mountains of Switzerland at 1300 m with heavy rime on rotor blades. Rime and ice substantially reduce energy production (see graph). (R. Horbaty)



## Wind power in the mountains: examples from Switzerland and Norway

Worldwide, wind power installations have a capacity of 16,000 MW and produce more than 20,000 GWh. Growing at more than 30% a year, wind energy production is becoming a serious component of the electricity market and can be regarded as a prime example of sustainable development. With recent price increases for oil and gas, wind power is now the cheapest source of electricity in the USA. Globally, development is moving away from coasts, either to large offshore wind parks in the sea or to inland locations including mountain regions.



### Wind power in the mountains

Mountain regions have many specific climatic conditions. Valley winds starting from south slopes (north slopes in the southern hemisphere) are characteristic. When the valley bottom slopes, canyon winds may blow either up or down the valley. Winds blowing down the lee side of mountains can be very strong. Examples are the *foehn* in the European Alps, the *chinook* in the Rocky Mountains, and the *zonda* in the Andes. Wind velocities over mountain ridges or crests are higher than in surrounding areas. However, the steeper the slope and the rougher the surface, the stronger the turbulence, which may remove the advantage of higher wind velocities.

### The Swiss wind energy context

Wind power could supply 3.5% of Switzerland's electricity demand. However, the development of the wind energy market has been slower than in neighbouring countries. Existing projects show that, in very good locations with modern converters, capacities of up to 2000 full load hours are possible. The production costs of the electricity are about 0.13 US\$/kWh (hydropower: 0.03–0.12 US\$/kWh). Wind power also provides highly welcome winter electricity from a renewable source at times of peak demand.

However, many high-potential areas in mountains and other cold regions are heavily affected by rime and ice. At an altitude of about 2000 m, icing conditions must be expected 10 to 30 days per year, substantially reducing the production capacity of a wind power plant. Wind power exploitation in mountain areas is further restricted by difficult grid connections and access.

Wind power installations also have impacts on landscape quality. Given Switzerland's intricate landscape, no large wind parks are conceivable. Regional coordination and the active inclusion of landscape protection and conservation groups are helpful in finding broadly accepted solutions when constructing wind power installations.

### The wind energy industry

Europe's highest wind power installation is operated on top of the Titlis, at 3000 m. Due to technical hitches, icing, and very strong turbulent winds, the energy production of this 30 kW installation is less than expected. An 850 kW wind power installation on the Gütsch (2400 m) above Andermatt in the Central Alps is planned for 2001. Experience with the construction and operation of this large wind turbine will be valuable for further projects in the moun-



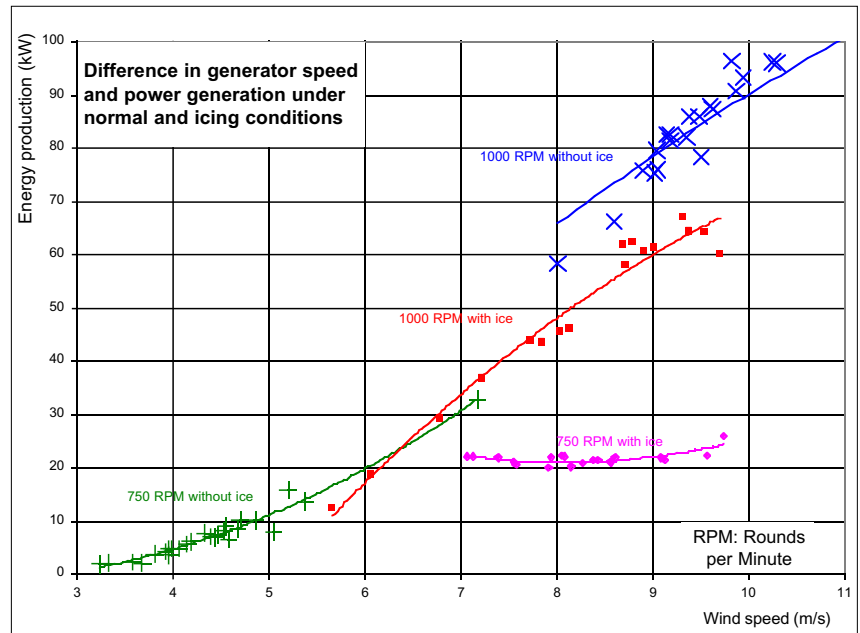
tains, particularly to supply energy for snow cannons in tourist areas, where the landscape has already been heavily impacted by tourism infrastructure.

While there is currently no wind power industry as such in Switzerland, Swiss firms are increasingly producing components for wind power installations, small wind installations, and engineering tools, such as modelling software for complex terrain. Given the limited access and the severe climate experienced at both offshore and mountain sites, installations must be very reliable. Hence there are also market opportunities for the expensive but high-quality Swiss electrical and gauge industry. A substantial domestic market will increase the sales potential for all these products and is a prerequisite for successful further developments.



### Wind power: an option for mountain farmers?

Wind power installations have great potential at windy locations in mountain farming areas. Production for hamlets or Alpine cooperatives – “green energy for green products” – is possible, as is the sale of electric energy to others, such as ‘green’ energy suppliers. Wind power installations can be attractive excursion destinations; guided tours and direct sales of agricultural products can bring additional return to energy production and sale.



### Energy policy

The future growth of the wind energy market – and with it a sustainable and economically meaningful production of energy – will depend strongly in Switzerland, as in other countries, on political consent for the development of renewable energies.

Debate in Parliament on the electricity market bill has led to very positive results, such as a legal requirement to declare the source of electricity, direct access for renewable energy, a single network company for high-voltage transmission, and refunding by this company of back-supplied current. After this legislation comes into effect, there will be good basic conditions for developing wind power in Switzerland.

*Robert Horbaty*

Power curve of a 150 kW wind turbine at 1300 m in the Jura Mountains of Switzerland. Icing reduces the speed (RPM) of the rotor blades even in high winds, which leads to a significant reduction in energy production compared to lowland areas. (R. Horbaty)

Working under extreme conditions: installation of a 30 kW wind turbine on Mt. Titlis (3000 m) in the Swiss Alps. (von salis communication)

### Wind power in Norway

The Norwegian utility Nord-Trøndelags Elverk is planning a 15 MW wind farm of ten turbines in **Vikna**, north of Trondheim. Officials have apparently been pleased with the output and operation of the existing 2.2 MW wind farm of turbines at the site on top of a steep coastal mountain. The availability has been 95% and the plant has produced more energy than expected in this rainy area. A specially developed lightning protection system has reportedly helped the turbines survive several strikes.



(VESTAS WIND SYSTEMS A/S)

At a global scale, fuelwood remains the main source of energy for cooking and heating in mountain households.

Collecting fuelwood – a burden for an increasing number of people in mountain areas.  
(U. Lutz)

Mountain forest in Sagar-matha National Park, Nepal. In many mountain areas around the world, forests have diminished due to increasing demand for fuelwood.  
(T. Kohler)



## Sustainable fuelwood use in mountain areas

At a global scale, fuelwood remains the main source of energy for cooking and heating in mountain households. In many mountain areas, especially in developing countries, there are no readily available energy substitutes. While energy-saving devices are being developed, mountain people can often not afford them. A long-term perspective is required for sustainable development of energy from fuelwood. This must not only be based on supply and demand and the dissemination of appropriate technologies, but also on the local socio-economic situation, including property rights and access to resources and technologies.



As the availability of fuelwood decreases, more time is required for its collection. Continuous unsustainable use of fuelwood forces rural people to use other biomass fuels, further degrading the environment. Those with higher incomes often decide to switch to kerosene, electricity, or gas. However, if these are not available or if the supply is not reliable – a common phenomenon in mountain areas – they may decide not to upgrade their fuel. Likewise, where fuelwood is scarce, people may downgrade to lower quality fuels. Fuelwood 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 widespread unemployment, the opportunity cost of time for unskilled people is lower than the price of fuelwood. Thus fuelwood will continue to dominate the mountain energy scene in the foreseeable future.

### Approaches to sustainability

Most governments and donor agencies have perceived fuelwood in terms of an energy demand and supply problem. This has led to recommendations to plant more trees, reduce consumption by introducing improved technologies, and upgrade the quality of biomass fuels. Modern cooking and heating stoves, biomass briquettes, and gasifiers fired by fuelwood can be exploited for meeting different end uses such as motive power, cooking, heating, and lighting. However, these interventions have often failed due to inadequate evaluation of the diverse traditional technologies and lack of regard for the socio-cultural values of mountain people, particularly women.

Biomass fuel production and use are intimately integrated into broader processes of resource management in local production systems. Fuelwood problems emerge gradually, as people respond to a variety of pressures on resources. This means that fuelwood stress rarely manifests itself as a simple short-

### Current trends in the Himalaya

In mountain areas, demands for space heating are greater than for cooking. For example, in the mountains of Nepal, 32% of the energy required by households is used for cooking and 56% for heating, compared with 40% for cooking and 36% for heating in the lower hill areas. The cooking, heating, and process heat requirements of small cottage industries are also fulfilled by fuelwood. The heavy dependence on fuelwood is made worse by the low level of efficiency of utilisation of this source – typically below 20%; and by the creation of health hazards, particularly for women who are the managers, producers, and users of energy at the household level.

Across the Himalaya, the demand for fuelwood exceeds the sustainable supply, and thus the process of destruction at the forest margin is common over much of the region.



age of fuel. It reflects the failure of local and national governments to establish the conditions that would allow efficient and sustainable allocation of land and resources between woods and cropland, food and wood production. Issues related to the distribution of control over decisions concerning land and other resources lie at the heart of effective fuelwood policies and programmes for mountain areas.

Activities to be undertaken in a fuelwood-led energy approach will vary according to local conditions. However, a series of general policy interventions can be defined. Property rights, especially for the groups experiencing the worst problems over access to fuelwood resources, must be secured. Market functions must be improved by eliminating policy-induced distortions in the prices of different types of energy resources and technologies. Access to and management of various renewable energy technologies and commercial fuels need to be improved so that mountain people have the options to make appropriate decisions. Many technological options, which are not affordable in the present context, may become affordable if properly integrated with community, social, and agro-forestry schemes, and income-generating activities. Planning institutions generally need to be strengthened,



and coordination between agencies – and also with the private sector – needs to be improved, reflecting the cross-sectoral nature of fuelwood issues. Finally, local people should be directly involved, through effective institutional structures that give them real control over the decisions that affect their lives.

*Kamal Rijal and Binayak Bhadra*

A couple enjoying food prepared on an improved mud-built cooking stove. Apart from creating a smoke-free environment, an improved stove can double energy efficiency in comparison to traditional cooking devices such as tripods. (K. Rijal)

| Sectors             | Traditional energy devices                          | New options available  |
|---------------------|---|--|
| <b>Cooking</b>      | Traditional stoves (3–10%)<br>Charcoal kiln (3–10%) | Mud-built improved cooking stoves (15–20%)<br>Briquetting technology and stoves (50%)<br>Efficient charcoal kiln (25–30%)                          |
| <b>Heating</b>      | Tripod stand (3–5%)<br>Charcoal kiln (3–10%)        | Metal stoves with different designs (25%)<br>Briquetting technology and stoves (50%)<br>Efficient charcoal kiln (25–30%)                           |
| <b>Lighting</b>     | Wooden stick of chir pine (n.a.)                    |  |
| <b>Process heat</b> | Traditional fuelwood kiln (10–15%)                  | Efficient fuelwood kiln (25–30%)<br>Briquetting technology and end-use device (50%)<br>Efficient charcoal kiln (25–30%)<br>Biomass gasifiers (40%) |
| <b>Motive power</b> |   | Biomass gasifiers (40%)  |

Figures in brackets: efficiency of energy conversion in percent.

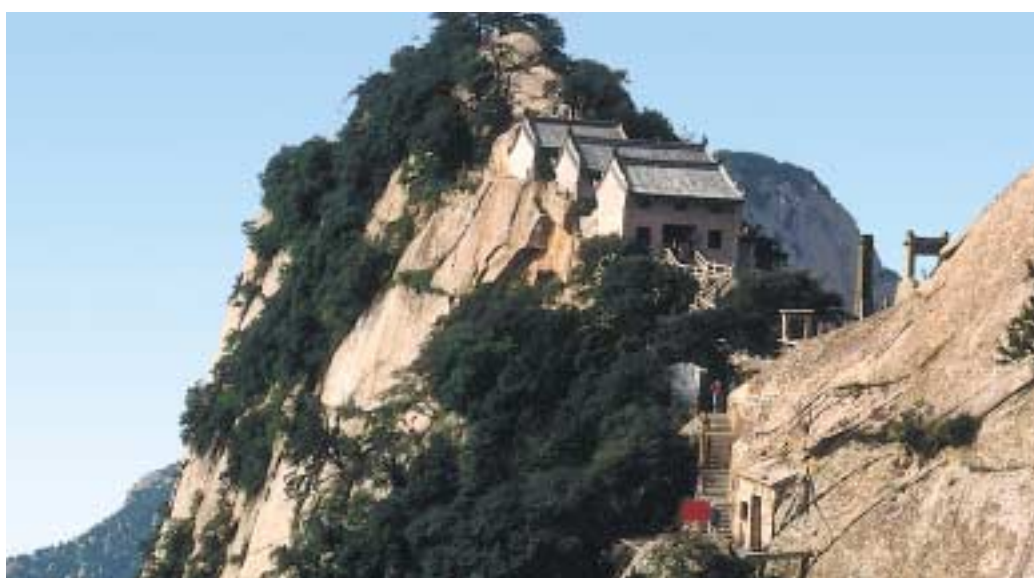
**Fuelwood-based traditional energy devices and new technologies employed in mountain areas. The new options increase energy efficiency considerably; this in turn can reduce the workload of women who collect firewood and relieve pressure on scarce wood resources. (Source: ICIMOD and CRT, K. Rijal)**

*In mountain areas, the demand for space heating is greater than for cooking. In the mountains of Nepal, 32% of the energy required by households is used for cooking and 56% for heating, compared with 40% for cooking and 36% for heating in the lower hill areas.*

## The cultural and spiritual dimensions of mountain energy

As the highest and most impressive features of the landscape, mountains evoke a profound sense of wonder and awe. Storms thundering about their peaks, the dramatic play of light on their summits, their towering heights and plunging chasms – all create impressions of overwhelming power and grandeur. People around the world have long regarded the awe-inspiring power of mountains as a manifestation of spiritual energy and meaning.

North Peak of Hua Shan, China. One of the five major sacred mountains of China, Hua Shan has long been a favourite haunt of Taoist hermits seeking to become one with the spiritual essence of nature. (E. Bernbaum)



The ancient Chinese believed the mountains to be so charged with spiritually transformative powers that their term for embarking on religion means “to enter the mountains.” Moses was called to the top of Mount Sinai, wrapped in cloud and thunder, to face God and receive the Ten Commandments and the Torah. Native Americans climb hills and peaks on vision quests to expose themselves to spirit beings who could guide them. Many hikers and climbers now go to mountains in search of spiritual inspiration and renewal.

### Mountain deities

For many cultures and traditions, the spiritual energy of mountains comes from, or takes the form of, deities who reside on or within mountains. Hindus regard Mount Kailas in Tibet, for example, as the abode of Shiva, one form of the supreme deity. Others, including communities in South America and New Zealand, revere the mountains themselves as their ancestors. For Western monotheistic traditions, mountains can be places of worship where one can communicate with the supreme deity.

The source of the spiritual energy of mountains can also be impersonal or natural. Chinese landscape paintings seek to awaken a sense of the Tao, the spiritual essence of nature that can be glimpsed like a mountain peak materialising out of the mist. For Western artists and poets,

### Pilgrims help restore a mountain landscape

The motivation for pilgrimage can be a powerful force for protecting the environment and improving local conditions. An innovative program at Badrinath has Indian scientists and priests working together to inspire pilgrims and others to replant trees for reasons that come out of their own religious and cultural traditions. They draw, in particular, on the idea that people can enhance their pilgrimage experience and obtain additional blessings by helping to restore an ancient forest sacred to the deities whom they have come to worship.

The ancient Chinese believed the mountains to be so charged with spiritually transformative powers that their term for embarking on religion means “to enter the mountains.”



the uplifting physical characteristics of mountains awaken a sense of the infinite and the sublime. Jean-Jacques Rousseau wrote, "In effect, it is a general impression experienced by all men, even though they do not all observe it, that on high mountains, where the air is pure and subtle, one feels greater ease in breathing, more lightness in the body, greater serenity in the spirit."

### Blessings from the mountains

The spiritual energy of mountains can be a source of blessings; peaks such as Mount Kenya, Popocatepetl in Mexico, and the San Francisco Peaks in Arizona are revered as generators of rain clouds, places of springs, and headwaters of rivers on which numerous societies depend. As sources of life, mountains may provide the blessing of fertility; for example, many elderly women climb China's Tai Shan to make offerings to have grandchildren.

Mountains are also viewed as major sources of healing. Female shamans in Japan and Korea routinely climb sacred mountains to charge themselves and conduct healing rituals for their patients. Andean *curanderos* or traditional healers draw their powers and guidance from their relationship to sacred peaks. The extreme climates and diverse ecosystems of mountains make them major sources of medicinal herbs throughout the world. In Europe, many sanatoriums have been located in mountains, based on the perception that the mountain air and environment have special curative properties.

Much of the modern appreciation of mountains derives from the perception of them as sources of spiritual and physical well-being. John Muir used this perception with great effect to help start the environmental movement in the United States: "Climb the mountains and get their good tidings. Nature's peace will flow into you as sunshine flows into trees. The winds will blow their own freshness into you, and the storms their energy, while cares will drop off like autumn leaves."

### Harnessing spiritual energy for development and conservation

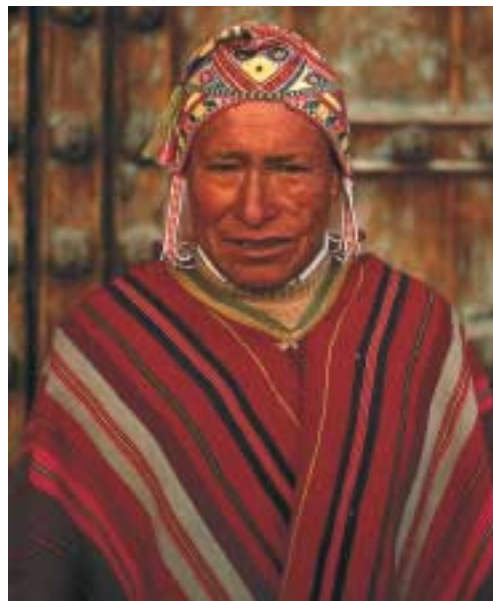
The spiritual energy of mountains attracts millions of pilgrims and tourists throughout the world, bringing money to local economies, but also leading to adverse effects on the environment and the sacred and cultural value of the sites. Many more pilgrims than trekkers visit the Himalaya, and heavily frequented mountain shrines are severely degraded, with deforestation, litter, sewerage, overcrowding, and other problems. Mass tourism with noisy buses has made contemplation nearly impossible at



the Greek monasteries of Meteora, and most of the monks have left for Mount Athos. Such an impact will eventually destroy much of what makes a mountain site or pilgrimage attractive to tourists.

Tourism and other kinds of development should respect what makes a particular place spiritually or culturally significant. If, for example, a mountain is viewed as a sacred centre off-limits to climbing, visitors could be encouraged to circumambulate rather than climb it. If the presence of tourists interferes with traditional religious practices or the special quality of the experience, restrictions may need to be placed on the number of visitors and where they can go. Any truly sustainable development of a mountain site should maintain the spirit of the place in the eyes of those who see it as a source of spiritual energy and meaning.

*Edwin Bernbaum*



Dominating the cities of Seattle and Tacoma, Mount Rainier stands out as an icon of the region. The site of a major national park, the mountain has played a leading role in the development of mountaineering and the environmental movement in the United States of America. (E. Bernbaum)

Andean *curandero* or traditional healer, Peru. Many of these healers draw their powers and guidance from their relationship to sacred mountains. (E. Bernbaum)

On average, our ability to do physical work decreases by 3% for every 300 m of altitude gained.

People who live for generations at high altitudes, such as these villagers from Bolivia's High Andes, show genetic adaptation, which helps them survive in often hostile high mountain environments. Some animals such as the llama and the alpaca in the Andes and the yak in the Himalaya are also capable of adapting to high altitudes, which makes them a valuable resource for mountain communities. (AGRUCO, Bolivia)

Modern means of transport such as airplanes and helicopters have greatly facilitated access to high altitudes. Those who are unacclimatised, such as most tourists, may be tempted to go too high too fast and can be affected by a variety of altitude-related illnesses. (T. Kohler)

## Human energy in the mountains

The livelihoods of many millions of people living at high altitudes depend not only on wood, animal power, fossil fuels, and renewable energy sources, but also on human physical effort expended in subsistence activities such as agriculture and pastoralism, or for payment, particularly in mining and tourism. At the same time, new means of transport, increasing transit across mountains, and the growth of tourism and mountaineering mean that the number of people visiting mountains – including high altitudes – is increasing rapidly. Consequently, it is important to understand the constraints on travel and work at high altitudes.



Three quarters of the energy released in the human body is in the form of heat, leaving only one quarter for the work of respiration, circulation, and other organic functions, as well as for physical and mental exertion. A resting adult at sea level burns 60–100 calories of fuel (food or body tissue) per hour: an average of 2000 calories per day. At 2500 m, this figure increases to over 2200

calories per day, and at 4000–5000 m to over 2500 calories per day. At all altitudes, hard work requires three times as much as these average figures indicate. The amount of oxygen required to release this energy varies depending on the individual and on metabolic factors. When the available oxygen supply does not meet demand, the body falters and may fail.



### High energy requirements for mountain work

Energy is particularly necessary in mountain environments, not only for organ function and work but mostly to produce and conserve body heat in the intense cold and wind chill. While other species have different protections against cold such as fur, thicker hair, or feathers, humans rely on shelter and special clothing. However, our ability to do physical work decreases by 3% for every 300 m of



### The hazard of high altitude combined with wind

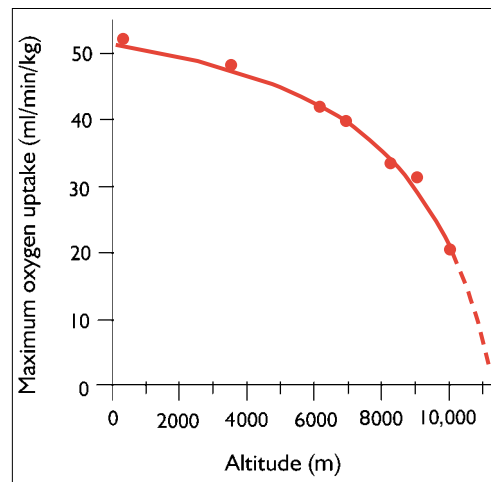
Air temperature perceived by humans is strongly affected by wind. A temperature of  $-6^{\circ}\text{C}$  in a light breeze of 25 km/h feels like  $-20^{\circ}\text{C}$  in calm air.

altitude gained; the rate of decrease is slightly larger at much higher altitudes. For sea-level people going to a high altitude, work capacity improves only very slightly over time as they adjust to the lack of oxygen in the process of acclimatisation. Breathing and heart rates rise, and new red blood cells and haemoglobin are produced to increase the oxygen-carrying capacity of the blood. Yet, at high altitudes, even well-acclimatised lowlanders have a lower work capacity than those coming from these altitudes. Long experience shows, for example, that miners coming from low altitudes can acclimatise, but the stress of working at a high altitude limits productivity and can be a long-term health hazard.

### Acclimatisation and adaptation

People ascending from low to high elevations are subject to a variety of altitude-related illnesses if they go too high too fast. Most people are unaffected at 2000 m, but almost everyone has symptoms of mountain sicknesses if they go rapidly above 4000 m. However, most individuals who ascend slowly to moder-

ate elevation acclimatise, some more slowly than others. Conversely, people who live for generations at higher altitudes show genetic adaptation, reflected in characteristics such as greater lung capacity, lower blood pressure, and blood which is more effective at diffusing oxygen into the tissues. Mountain sicknesses affect thousands of tourists who go up too rapidly to even moderate elevations (2500 m–3500 m). Every year, they result in coma and death for a number of visitors. Some, but not enough, improvement has been achieved by more widespread information about the risks of going too high too fast.



Work capacity decreases progressively with increasing altitude, due to decreasing oxygen uptake at higher elevations. Work would be impossible at about 10,000 m. (adapted from: C. S. Houston)

Humans function best near sea level and, as they go higher, face many problems. Mountains of even modest elevation can be dangerous to unprotected and uninformed visitors. The combined effect of lack of oxygen and exposure to wind is important even on low mountains and becomes a formidable danger on high ones. Lack of oxygen and freezing temperatures, storms, avalanches, and rockfall make very high mountains extremely hazardous. Even those well trained and protected are unable to do as much mental or physical work as they can at lower elevations.

*Martin Price, Charles S. Houston*

A volunteer, fitted with measuring instruments, is tested for maximum work capacity under conditions simulating high altitude. (C. S. Houston)



### Common altitude illnesses

A common altitude illness is Acute Mountain Sickness, characterised by headaches, nausea, weakness and other symptoms. It is more unpleasant than serious and usually disappears in about 48 hours. By contrast, High Altitude Cerebral Edema is dangerous; it manifests itself in changes in mental activity, judgement, energy, and muscular coordination, progressing to coma and death if not treated. High Altitude Pulmonary Edema causes shortness of breath and coughing of blood, and may lead rapidly to coma and death.



Transportation difficulties in the rainforest in the foothills of the Carabaya, Peru. (F. C. Engle)

# Mountains and transport

## Dilemmas of transport and energy development in Peru's Cordillera Carabaya

Roads built through remote mountain ranges represent development opportunities but may also lead to rapid, and often destructive, social and environmental changes. Roads permit economic development, but this must be carefully tailored to local conditions to minimise unintended consequences and degradation. A balance in project design that safeguards the interests of local inhabitants and ensures environmental preservation – even if this requires some lowering of economic objectives – may lead to long-term economic benefits that far exceed those of shortsighted, hastily implemented projects.

In southern Peru's Cordillera Carabaya, glaciers loom directly above tropical rainforests. The region is typical of the ecologically impor-

tant yet economically undeveloped regions along the steep Amazonian slope of the central Andes. Its topographic complexity and remoteness long kept it off national and international agendas. Now, the Carabaya's considerable economic potential in terms of resource exploitation, tourism, and hydroelectric generation is receiving increased attention.

### Roads: the Transoceanic Highway

The key to current development initiatives is the Transoceanic Highway, which aims to link Pacific Basin markets with the Amazon Basin and Brazil. Begun as a local-scale response to the stress of social conditions in the 1950s in highland Peru, the road has grown in scope and importance, and its completion is now a development objective serving both national and international agendas. Its impacts may be economically beneficial to Peru in the short-term through increased trade and resource extraction, but longer-term benefits are questionable, especially with regard to the environment and regional populations. In particular, the highway enters the Amazon rainforest at the foot of the Carabaya between two existing nature sanctuaries: Manu National Park, a World Heritage Site; and Tambopata-Candamo Reserve, which may host the greatest biodiversity on Earth. Hundreds of square kilometres of this rainforest have been degraded near the road at Hueypetue, where a gold rush has been ongoing since the early 1990s. Existing roads have fuelled this boom by allowing the import of over 1000 pieces of heavy earth-moving machinery and daily convoys of fuel trucks to support the mining and facilitate immigration of workers. The highway's completion will lead to further extraction of gold and timber, and





the conversion of rainforest to agricultural land as pristine forests become more accessible.

### **Tourism: a passing opportunity?**

The most sustainable and potentially greatest economic benefit to Peru of the Transoceanic Highway could come from managed development of a tourist industry facilitated by improved access to a region rich in culture and tradition. Neither local nor national governments have yet exploited this alternative, though tens of thousands of tourists pass nearby each year while visiting the Cuzco and Lake Titicaca regions. A sustainable tourist industry in the Carabaya would hopefully also diminish the drive for more destructive activities.

### **Hydropower: the San Gaban scheme**

The building of roads into the Carabaya has allowed some of the region's considerable hydroelectric potential to be realised. The foothills are one of the wettest zones on Earth, and glaciers in adjacent highlands ensure sustained river flows in dry seasons. The San Gaban II plant, the first of four units of a major hydropower initiative, became operational in 2000, significantly increasing the electrical supply for urban areas and industry in southern Peru. The US\$ 208 million cost of this 110-MW facility, built by a consortium of Peruvian, Brazilian and French concerns, came primarily from Japan's Eximbank. Made possible by the Transoceanic Highway, the San Gaban scheme is playing a significant role in accelerating road construction to bring in heavy engineering equipment.



Yet there are flaws in this development success. San Gaban II offers impetus for development and modernisation across the region, but has yet to provide electricity promised to most of the Carabaya's rural people. It bypasses local inhabitants for greater national interests – including two multinational mines, which absorb 32% of the electricity generated. Also, the valley is prone to natural hazards: earthquakes, floods, landslides and debris-flow avalanches. A major hydropower plant further north along the Andes, at Machu Picchu, was destroyed in 1998 by an avalanche caused by glacial melting associated with an El Niño event. The input from San Gaban II has eased the precarious state of electrical supply in southern Peru since this setback, yet the possibility that a similar disaster could befall the San Gaban scheme must be appreciated and contingencies provided.

*Anton Seimon*

Glaciated peaks feed 4860-m-high Lake Sibinacocha, Peru. After years of rises due to climatic anomalies, a recent drop in the lake level has rendered a new hydroelectric plant on the lake non-functional, representing at least temporary failure for an improperly designed development project. The lake supports a complex ecosystem with high biodiversity, including domesticated animals such as alpaca and wild species such as vicuña. (A. Seimon)

*The Transoceanic Highway will be the first paved road to cross the Peruvian Andes and connect with the Trans-Amazon Highway network in Brazil.*



Page 26, bottom:  
Bridge under construction over the Inambari River, Transoceanic Highway. (A. Seimon)

The Transoceanic Highway descends through the 2500-m-deep canyon of Ollachea River, Peru, offering much potential for tourism that will need to be carefully managed to safeguard the region's peoples and environment. (A. Seimon)



## The challenges of Alpine transit traffic

Straddling 8 countries, the Alps are home to over 11 million people and a recreational area of global importance, but they are also a major natural barrier to continental passenger and goods traffic. For centuries, people crossed the Alps on foot and with pack animals. The need to increase the capacity of transit routes became obvious at the beginning of the Industrial Revolution. The construction of the railway transit routes in the late 19th century opened the age of mass transport. In the 20th century, railway construction was limited to increasing the capacity of the existing routes while road infrastructure was greatly expanded due to the popularity of the automobile. Today, 20 transit routes for passenger and goods traffic cross the Alps. Nine of these are of international importance.



Freight train hauling containers across the Alps.  
(SBB/A. Boillat)

Transit of goods across the Alps is dominated by road traffic. Local communities along the main transit routes are exposed to increasing levels of noise and air pollution, and air quality standards are exceeded over extended areas.  
(Alpeninitiative)

### Trends in rail and road transit

Passenger and goods traffic on the Alpine transit routes grew vastly during the last two centuries. Over the same period, the relative proportion of the total traffic by rail and road changed dramatically: except for goods transport through Switzerland, Alpine transit traffic mainly uses roads. Trends in transit traffic are a precondition for as well as a consequence of economic and political trends in Europe, such as growth, opening up of markets, European integration, regional specialisation, and just-in-time production.

### The central dilemma: dispersion of benefits, concentration of costs

The effects of Alpine transit traffic are manifold, ambivalent and varied. In the Alpine area, the positive effects come from increased accessibility: centres outside the Alps are accessible to Alpine inhabitants, and the Alps are accessible to tourists. Positive effects on employment are both direct (main-

tenance of traffic routes and traffic services) and indirect (tourism, catering, and sports). The negative effects are associated with constructing and operating transport infrastructure in difficult terrain as well as with the high volume of traffic. These include the high costs of construction, maintenance and operation; the large areas required for transport systems; fragmentation of natural habitats and their damage by pollutants and natural disasters; interference with sensitive landscapes; pollutants, noise, and vibration; catastrophes relating to transport of hazardous materials and accidents in tunnels; and decreased quality of life for people, fauna, and flora.

Outside the Alps, economic growth due to expanded markets for raw materials, agricultural and industrial products and tourism is a positive effect. Negative effects are more indirect. For example, trans-Alpine traffic





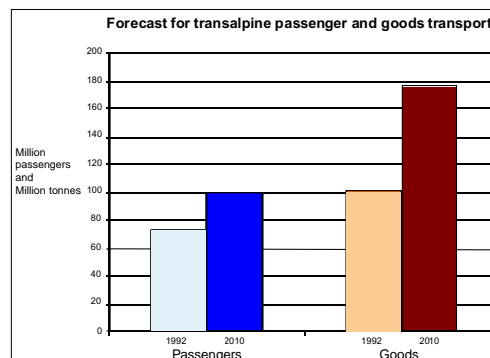
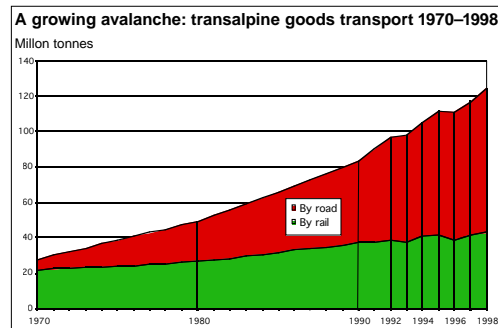
encroaches upon transport networks and living space in neighbouring areas.

The central dilemma of trans-Alpine traffic is the contradiction between the continental dispersion of the benefits and the local concentration of costs. While the benefits are spread over a wide area including centres of economic development outside the mountains, the costs of infrastructure and operation as well as the negative impacts on human lives and the environment accrue almost only within the Alps.

### Challenges and policies for Alpine transit traffic

In view of the trends forecast in transport demand, the objectives of sustainable development and the Alpine Convention, the eight Alpine countries and the European Union (EU) have committed themselves to discouraging further growth of Alpine transit traffic on roads, by shifting as much cargo as possible from road to rail. No new transit roads will be built. The railway infrastructure will be further extended and customer- and environmentally-friendly public transport systems promoted instead.

Switzerland modified its transport policy along these lines some time ago and secured this position in an agreement with the EU. The main aim is to shift goods traffic from road to rail. The number of truck trips across the Alps – 1.3 million in 1999 – will be halved to 650,000 per year by 2009 at the latest. Six supply and demand measures will be used. First, promoting combination transport, by enlarging railway tunnel sections for pick-a-back transport and building and operating terminals, some in neighbouring countries. Second, building two New Rail Links through the Alps. Third, increasing the general truck



weight limit from 28 to 34 tonnes (from 2001), and then to 40 tonnes (from 2005), with limited quotas for 40-tonne trucks (from 2001). Fourth, introducing power- and emission-related taxes for trucks over 3.5 tonnes (from 2001). Fifth, prohibiting trucks over 3.5 tonnes at night and on non-workdays. Finally, stopping further development of road capacities.

It remains to be seen whether these measures will achieve the desired effect. In any case, the problems of Alpine transit cannot be solved by the Alpine countries alone; a comprehensive and co-ordinated European transport policy is needed.

*Peter Keller, Christian Heimgartner*

Transit of goods through the Alps more than quadrupled between 1970 and 1998. Most of this increase was absorbed by road traffic. While rail transit was three times greater than road transit in 1970, this ratio has since been reversed.

(Source: LITRA (2000), Alpenquerender Güterverkehr, Datentabelle, [http://www.litra.ch/Ausw\\_D/Vadem/alptrst99.htmD](http://www.litra.ch/Ausw_D/Vadem/alptrst99.htmD), Bern)

Owing mainly to general economic growth and increasing European integration, transit of both passengers and goods through the Alps is expected to grow in future. This is the background of the political move to increase rail transit capacities (new tunnels) in order to shift goods transit from road to rail.

(Source: Prognos AG, Regional Consulting and ISIS (1997) Study of the Development of Transalpine Traffic (Goods and Passengers) Horizon 2010, Basle, Vienna and Paris)

### New Rail Links through the Alps (NRLA): the example of Switzerland

|                         |   |
|-------------------------|---|
| Aim:                    | Increase railway transport capacity and quality through the Alps, with the main objective of shifting transalpine goods transport from road to rail |
| Measures:               | Construction of two transit rail routes   |
| Core elements:          | Construction of two new base tunnels: Lötschberg (35 km), and Gotthard (57 km), and upgrading of the main feeder lines                              |
| Period of construction: | 1999–2016 (including main feeder lines)   |
| Costs:                  | US\$ 8.5 billion  |
| Financing:              | Secured by special funds (heavy vehicle tax (LSVA), mineral oil tax, value-added tax (1‰), and debt (max. 25%))                                     |
| Political context:      | Transit Agreement between Switzerland and the EU (1992); Bilateral Land Transport Agreement between Switzerland and the EU (1998)                   |

(Source: Swiss Federal Office of Transport (2000) [http://www.bav.admin.ch/d/fs/fs\\_d.cfm](http://www.bav.admin.ch/d/fs/fs_d.cfm))



Tunnel drilling operations in Switzerland. New base tunnels play a key role in Alpine countries in increasing railway capacity through the Alps. (ALPTRANSIT AG)



The road along the Paso Jama section of the Corredor del Capricornio at 4400 m in Chile. Photo taken in 1990, before reconstruction and pavement. (M. Grosjean)

Bundling communication and energy infrastructure along the Corredor del Capricornio. This photo, taken on the Chilean side in 1997, shows the new paved road and a train transporting copper from Chuquicamata mine, one of the world's largest open pits for copper exploitation. The high voltage power line provides the mine with electricity. The gas pipeline runs alongside the road, rail track and power line. (M. Grosjean)

## Crossing the Atacama Desert: a link from the Pacific to the Atlantic

The Atacama Desert in the central Andes of northern Chile is one of the driest places on Earth. It ranges from sea level to a mountain plateau at 4000 m with peak elevations as high as 6700 m. Although it is an extremely hostile environment for humans, the Atacama Desert is economically attractive because it contains some of the world's largest deposits of copper, gold, silver, and lithium. It also occupies an important geopolitical position between Chile, Argentina, Bolivia and Peru, and has a long and unique history of trade and traffic.



The location of the Atacama Desert between the Pacific and the Atlantic coast, its vertical structure, and the contrast between very poor food and water resources and very rich metal ore deposits have meant that it has always been an area with intense exchange involving goods, people and cultures. While the central Andes was an area of economic integration from pre-Inca to Hispanic times, the emergence of nation-states in the 19th and 20th centuries resulted in the creation of borders, border disagreement, and periods of conflict. Two strate-

gic routes between Argentina and Chile were temporarily closed during the 1970s and 1980s when these countries were ruled by military governments, but there has been a continuous effort to keep these important transportation routes open.

### Developing high-capacity corridors for access and transit

The Peace and Friendship Treaty of 1984, restoration of democracy in both countries, globalisation of markets, foreign investments, and the emerging economic integration of South America have led to a remarkable economic development of the Atacama Desert, requiring new traffic and transportation infrastructure. Chile and Argentina established integration forums and prioritised 13 passes for trans-border infrastructure development. A visionary development plan, *Corredores Bioceánicos*, aims to link the countries of southern South America with harbours on the Pacific and Atlantic coasts, making their economies accessible to the Asian and European markets.







Argentina, Paraguay, Brazil and Uruguay. Parallel to the road, two natural gas pipelines, 941 and 876 km in length, were built to transport energy from east to west from the lowlands of Argentina across the Andes to newly built power plants on the Pacific coast in Chile. High voltage power lines bring the energy back to the metal mines and urban centres in the Atacama Desert. New harbours on the Pacific coast are under construction, to facilitate import of goods from the Asian market, and export of products from rapidly expanding metal mining. Since these developments are very recent, and analogues in the region are missing, many questions remain to be answered regarding costs and benefits for the local population and impacts on the mountain ecosystem.

*Martin Grosjean and Marcela Espinoza*

As high-capacity infrastructure was needed to facilitate the exchange of goods, shorter transportation routes along the *Corredor del Capricornio* were designed at altitudes up to 4800 m across the Desert. However, this remained a major technical challenge for various reasons. Though this area is extremely arid, very rare heavy rainfall causes serious damage and can block roads. The high elevation areas receive more than 300 freeze-thaw cycles per year; yet little is known about the long-term effects of frost-action in the area. The area is tectonically very active and earthquakes are frequent.

Since 1991, bilateral agreements between the governments of Chile and Argentina have led to coordinated infrastructure investments on both sides. In northern Chile and northwestern Argentina, the new Paso Jama road with full pavement was constructed for US\$81.9 million and inaugurated in January 2000. Goods are transported mainly from west to east from the 'duty free' harbours of Iquique in Chile to



Paso Sico section of the Corredor del Capricornio at 2500 m in Chile. The photo shows the damage caused by erratic heavy rainfall in the first rainy season after the new road was paved. (M. Grosjean)

Mountains as barriers to transit: the Argentinian side of the Paso Sico branch of the Corredor del Capricornio. (B. Jenny)

### From parrot feathers to cows and cars: fluxes of goods across the Atacama Desert

The Atacama Desert has a very long tradition of trade. Feathers of east Andean parrots in archaeological sites on the Pacific coast and marine shells found in the high Andes document trans-Andean exchange of goods for over 5000 years. The Inca trail (14th and 15th centuries) crossed the Atacama Desert from north to south, connecting Cuzco to Santiago. In the 19th and early 20th centuries, large caravans of cows (in 1909: 83,870 cows) walked from east to west from the Argentinian Pampa across the Andes to northern Chile, as all the food and water for the 70,000 people working in nitrate exploitation had to be imported. The cow caravans stopped when nitrate production ceased before World War II. Today, caravans of second-hand cars from Japan are driven in the opposite west-east direction across the Andes to Uruguay and Paraguay.



## The Karakorum Highway: accelerating social and environmental change in a formerly secluded high mountain region

The Karakorum Highway (KKH) connecting the lowlands of Pakistan with the autonomous Chinese province of Xinjiang has opened remote mountain valleys in northern Pakistan's Himalaya and Karakorum to the outside world. Construction began for strategic purposes, as Pakistan needed an all-weather road to gain administrative and military control of these mountains, owing to several periods of conflict between Pakistan and India and to the India-USSR geopolitical axis. While the resulting socio-economic integration of the region has improved living conditions, it has also led to an unsustainable flow of timber to the lowlands.



Timber is transported via motorable tracks to the KKH. (U. Schickhoff)

The KKH follows the Indus and Hunza river gorges through one of the world's geologically most active mountain regions. Constructed as a joint venture by China and Pakistan, it is the most spectacular compo-

nent of an extensive road construction programme in High Asia. Construction was hazardous: over 1000 workers were killed prior to the road's completion in 1978. The KKH was opened to the public in 1986, and is the backbone of an emerging transportation network of small jeep roads to side valleys. Half the length of this link road network was constructed in the last two decades.

### Examples of change triggered by the KKH

- imports of subsidised food and industrial consumer goods from the lowlands
- monetarisation of barter relations
- decreased importance of subsistence agriculture and shift to cash crop production
- increase in non-agrarian activities and diversification of incomes (tourism, trade, transport, military, administration)
- increased spatial mobility and migration of employees to lowlands
- growth of bazaars in Gilgit, the central marketplace

### Impacts on economy, society, and environment

The KKH provides infrastructure that supports and accelerates both socio-economic transformation and the exploitation of natural resources. Growing accessibility integrates even peripheral valleys into wider networks of interaction and communication. As exchange



relations intensify and external influences penetrate, far-reaching economic and socio-cultural change and innovation occur.

New dimensions of highland-lowland interactions have had far-reaching impacts on the agrarian economy. Subsistence production has become less important owing to subsidies for food supplies and transport rates and to the activities of development agencies, which assist farmers in marketing surplus products and cash crops – including introduced high-yielding varieties requiring imported mineral fertiliser. However, marketable cash crops cannot fully compensate for heavy imports of food from the lowlands that are paid for with migrants' money. The change in traditional economies has caused growing dependence on support from lowland political and economic centres, only recently mitigated to some extent by trade with Xinjiang.

Economic change is intimately linked to changes in social structure. Social position is no longer related to affiliation with identity groups or size of landholdings but judged by new criteria, such as level of education, income, and possession of vehicles, agricultural equipment, construction machines, hotels, and shops. Thus, traditional social stratification may change, as members of ethnic groups previously considered to have a low social status climb to higher social positions.

Radical socio-economic transformations have inevitable consequences for natural resource use, as vividly illustrated by the use of scarce forest resources. Exploitation of forests for lowland markets, triggered by desire for short-term profit, has increased substantially. Only in narrow zones high above the arid valley floors is there sufficient humidity to support small stands of conifers. The KKH and its road network have greatly improved the transport of timber, with clear benefits for commercial forestry in private forests. In addition, the monetarised economy forces many small households to use timber as a source of cash and to participate in illicit cutting and smuggling of wood. This increases pressures on the



Timber floated down the Indus River and stored at accessible sites to be picked up by lorries when road conditions allow. Floating timber is only possible during winter when the water level in the Indus is low. (M. Gumpert)

remaining forests. Given the excessive profits in the timber business due to high demand from the lowlands, forests are being degraded at an alarming rate.



Traditional subsistence agriculture has been declining in importance since the KKH was built. (U. Schickhoff)

### Outlook

Although the KKH initially appears beneficial for the livelihoods of mountain peasants, the transformation process is having ambivalent results. Mountain people welcome new opportunities. But decreasing subsistence levels, dependence on external food, and exploitation of resource-poor peasants by money-lenders all lead to new forms of social vulnerability. Adverse effects on forest resources must be mitigated by adopting new policies for sustainable forest management that aim to maximise ecological benefits, based on community participation and joint management.

*Udo Schickhoff*

Chinese lorry stuck at 4500 m below the Kunjirap Pass (4700 m), KKH. Although it is normally closed from November onwards, authorities try to keep the pass open as long as possible in wintertime in order to maintain trade links between Pakistan and China. (M. Gumpert)



| Accessibility increases pressure on forest resources  |  |
|---|--|
| Accessibility   | Decrease of forest stand density index 1969–1994 |
| Forest stands with high accessibility (distance to jeepable road less than 2 km)  | 30–85% in 11 of 14 stands                        |
| Forest stands with low accessibility (distance to jeepable road more than 8 km)   | 0–40% in 12 of 13 stands                         |
| Exploitation of forest resources along the KKH in Pakistan's Northern Areas has increased markedly due to improved accessibility and increasing demand in lowland areas. (Adapted from U. Schickhoff) |  |



Hairpin bend in the access road on the edge of a steep cliff, Simen Mountain National Park, Ethiopia. Routes such as the one shown here increase the danger of accidents, especially on rainy and foggy days. (R. Schaffner)

### Defining "100% Access"

In Switzerland, an access project is 100% successful when each person in an area is able to reach his/her house directly by car. In Ethiopia, the criterion is that the population of an area can reach the road within a day's walking time.

## Access road construction in Ethiopia and Yemen

Much of semi-arid northern Ethiopia is densely populated and often affected by droughts leading to chronic food deficits. To connect the remote Janamora District to the national road network, the government has constructed a road from the national highway through the rugged highlands. While it facilitates the transport of relief food aid and supports the region's development, it also runs partly through Simen Mountain National Park, declared a World Heritage Site because of its unique landscape and high biodiversity, with many endemic species and rare wild animals. Little attention was paid to the adverse effects of road construction on the Park's environment.



### Impacts of road construction

The road was largely constructed along ridges in order to minimise the number of water management structures, and is therefore much longer than necessary. Its construction used heavy equipment such as bulldozers, with the spoil being tipped down the slopes.

With increasing human activities, including grazing and road construction, the undisturbed wildlife habitat greatly decreased. The

road also cuts through the corridors connecting the northern escarpment with the ridges and peaks to the south, and destroyed much of the valuable high-altitude forest, mainly composed of indigenous species. Above the timberline, a wide band of fragile, delicate afro-alpine vegetation was destroyed along the road. Vegetation and topsoil were removed from roadside slopes and large quarry pits, exposing them to erosion. Side tipping of spoil caused further damage to forests and grasslands, also decreasing slope stability.

The new food relief centre on the Park border shortened the walking distance for local people by two days. Yet the thousands of people coming to this centre cut trees for cooking and overnight warming. As the road was built with heavy equipment, virtually no income was generated for local people, and they gain less income from tourism because trekking facilities are no longer required, as the Park can be visited by car in a day. No compensation was paid to farmers who lost

### Road network density of Switzerland and Ethiopia

|  | Switzerland | Ethiopia  |
|--|-------------|-----------|
| Area (km <sup>2</sup> )                | 40,000      | 1,100,000 |
| Population (million)                   | 7           | 55        |
| Length of road network (km)            | 70,000      | 24,000    |
| Road length/area (km/km <sup>2</sup> ) | 1.75        | 0.02      |
| Road length/population (m/person)      | 10          | 0.44      |

**In terms of area, Switzerland's road network is nearly 100 times denser than Ethiopia's. In terms of population, it is 23 times denser.**



grazing or agricultural land. Along the road, the establishment of tourism infrastructure and services is a problem since the impacts on biodiversity and wildlife would be negative at every location. The same is true for social infrastructure. The long stretches of road running along the escarpment are dangerous because they are often relatively steep and have sharp curves. The likelihood of accidents has increased, especially during rainy and foggy periods.

### Mitigating the impacts

To mitigate the road's environmental impacts, two re-alignments were proposed which compare different options according to ecological, socio-economic, and technical/cost criteria. Both options are in an advanced stage of discussion. The construction of the re-alignments will require comprehensive soil conservation and erosion protection measures. To avoid unnecessary damage to the fragile ecosystem, all construction will use labour-based techniques that minimise environmental impacts, decrease costs and dependence on mechanical equipment, and give local people income, expertise, and ownership. This approach has been confirmed by recent government policy for rural access roads. The new road will have a gravel surface which is adequate for the rather limited traffic. It is also narrower, designed to minimise the amount of spoil and its transport.

The re-alignments avoid agricultural land as much as possible. The loss of grazing and agricultural land will be compensated and, since construction will be during the dry season, it will not compete with agricultural activities, which are concentrated around the



rainy season. Labour-based road construction will be excellent for local income generation, as the project will be awarded to national contractors, who must recruit only local labour. About half the local people should be able to participate in road construction. Thus, 30–40% of the investment will go directly to them as wages, considerably decreasing their dependence on relief food during the construction stage – and later, at a reduced scale, during operation, as wages will be paid for maintenance by trained labourers. Income from tourism could also be generated for the government, through controlled collection of Park revenues, and for local people, through job opportunities as park guides and staff for the centre, if the authorities establish a Park centre and gate.

Stakeholder participation will be encouraged from the beginning as a suitable forum for discussions concerning the different actors and project issues. It will provide opportunities to inform the local stakeholders about the project's objectives and schedule, and of the need for their active participation.

*Urs and Ruth Schaffner*

Simen Mountain National Park, Ethiopia. Labour-intensive road construction generates much local income; 30–40% of construction costs will go directly to local people in the form of wages. (R. Schaffner)

*Labour-based road construction is usually not feasible in industrialised countries due to high labour costs. If heavy machinery is used, excavators are more appropriate than bulldozers in mountain areas, as they cause less damage to the environment.*

Improved rural access road in Yemen. Road construction and maintenance on such steep and dissected terrain is both technically demanding and expensive. (U. Schaffner)

### Criteria for access road projects in Yemen

In Yemen, the Social Fund for Development (SFD), a national non-governmental organisation financed by donors such as the World Bank, the European Union, and the Arab Fund, has an interesting approach to assess the viability of rural access roads. They use a mix between quantifiable and unquantifiable criteria and give each criterion an individual weighting.

| Criterion  | Points    |
|--|-----------|
| Poverty level of project area                              | 5         |
| Population benefiting (directly and indirectly)            | 3         |
| Economic potential/burden of area                          | 3         |
| Access to infrastructure (water supply, education, health) | 3         |
| Remoteness   | 2         |
| Suitability as road network extension                      | 2         |
| Per capita cost of road (US\$/beneficiary)                 | 2         |
| <b>Maximum score</b>                                       | <b>20</b> |



A minimum of 9 points is required for an SFD road project. The point distribution is decided according to established rules so that the result of the viability assessment is transparent and can be explained to the beneficiaries.



## Human power instead of machines: rural access roads in West Flores, Indonesia

For the 100,000 people living in the villages of the mountains of Manggarai District, West Flores, Indonesia, an area with considerable agricultural potential, roads are vital for survival. An all-year road link guarantees access to markets, hospitals and higher education, and is crucial for providing communities with fertilisers, construction material for houses, installations for drinking water supply, and other basic goods. However, road construction in such tropical mountain areas requires specific design and construction methods. Road construction started in 1985 and was completed in 1997. In 1994, a new component consisting of support for traditional self-help community efforts in building village roads and motorable tracks was added.



Removal of boulders along the excavated road bed using labour-intensive methods.  
(P. Hartmann)

A completed stone-paved district road in West Flores, Indonesia. An all-year road link guarantees access to markets, hospitals and higher education, and is crucial for providing communities with vital basic goods.  
(P. Hartmann)

### Designing and building the roads

The development of design standards involved consideration of more than just the mountainous topography. The soil conditions, extensive rock outcrops, the tropical climate, an average daily traffic of 20–30 vehicles with a maximum main axle load of 6–8 tons and a maximum speed of 30 km/h, and the use of labour-based construction methods were also important. Given these conditions, the four main characteristics of the roads are dry-stone retaining walls, a comprehensive drainage system, strongly built structures, and a hard-wearing carriageway.

A labour-based road construction project, with several hundred labourers spread over several kilometres of road, needs careful planning and organisation. The work is split into a number of clearly defined steps with specific and easily controllable construction activities. To secure high construction quality, a number of simple but very effective aids are

used. These include checking the correct shape of slope, ditch, and foundations with wooden templates; using pegs and string lines to guarantee the correct size of retaining walls, structures and carriageway, and a simple wooden clinometer to check the longitudinal alignment.

### Benefits for the region

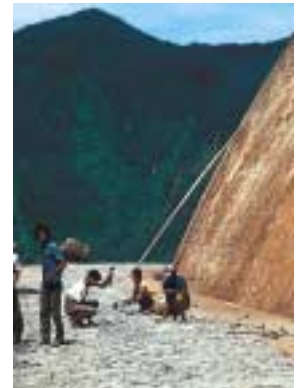
In total, 180 km of stone-paved roads and 40 km of earth roads were constructed, together with six reinforced concrete bridges, two stone arch bridges, and 30 major culvert drifts. The average construction cost for stone-paved roads, including an allowance for free community labour, was US\$ 24,000/km. By the standards of existing transport routes on Flores Island, the roads are of exceptional



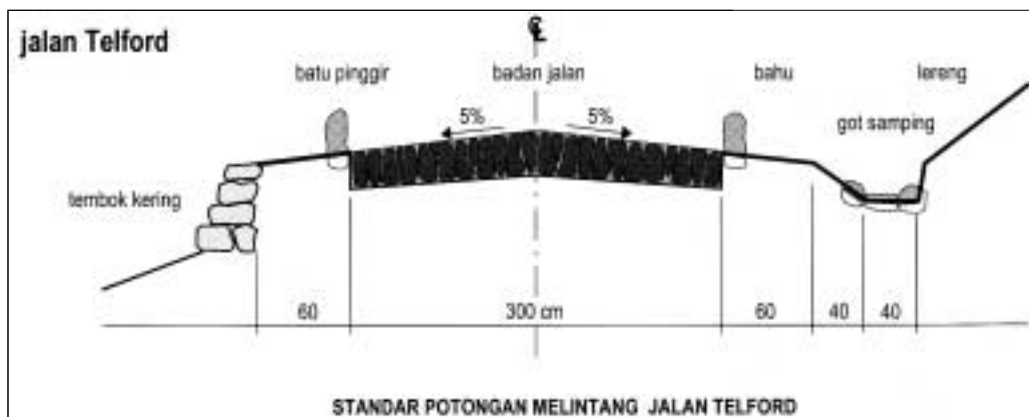


### Stages of labour-based road construction, West Flores, Indonesia

- setting out the road alignment
- clearing bushes, trees, and other vegetation, and removing boulders
- excavation to roadbed level by cutting out the existing side-slope – work that is carried out voluntarily by communities and usually requires adjustment
- general earthwork, including the correction of the dug road bed, adjustment of the backslope and removal of boulders
- construction of dry-stone masonry retaining walls with large stones collected locally, and a backfill of well-compacted gravel
- laying of culverts regularly spaced along the road, and construction of necessary structures, such as concrete fords, culvert drifts, and bridges
- digging a side drain along the road, including scour checks to reduce water velocity
- excavation of the foundation to pave the carriageway with stones, or excavate the camber base for earth roads
- laying c. 30 cm of stone paving, and sealing this with a mixture of gravel, sand, and clay to provide a smoother surface and prevent water from penetrating
- finishing work, such as protecting slopes and shoulders from erosion by planting grass; placing of kerbstones.



Wedging the stone paving with stone chips before applying the sealing.  
(P. Hartmann)



Standard cross-section for stone-paved roads. Figure taken from a construction manual for local technicians and village communities.

(Courtesy P. Hartmann)

quality, and thus most roads remain in good shape although an effective road maintenance system was not established.

The construction work required almost a million paid working days. Access to the district capital, markets, hospitals, and schools has improved greatly for the villages near the roads. Prices for farm produce and local handicrafts have increased. Supplies of consumer goods have improved, and prices have decreased. As a result of these economic improvements, the number of new or renovated houses along the roads is growing.

Hundreds of villagers were trained on the job as workers and craftsmen, and surveyors and foremen were trained for 17 sub-districts. Many villages near the roads have undertaken their own road projects without external assistance, achieving satisfactory results. Support for such traditional community self-help efforts achieved several results: the construction of more than 100 km of village roads by self-help labour, general realisation of the

need for a proper road survey by the local leaders, increased demand for the transport of passengers and goods, and requests from four neighbouring districts for support.

*Peter Hartmann*

Construction of the stone arch bridge on Mantar River, one of the show-pieces of rural road construction in West Flores.  
(P. Hartmann)





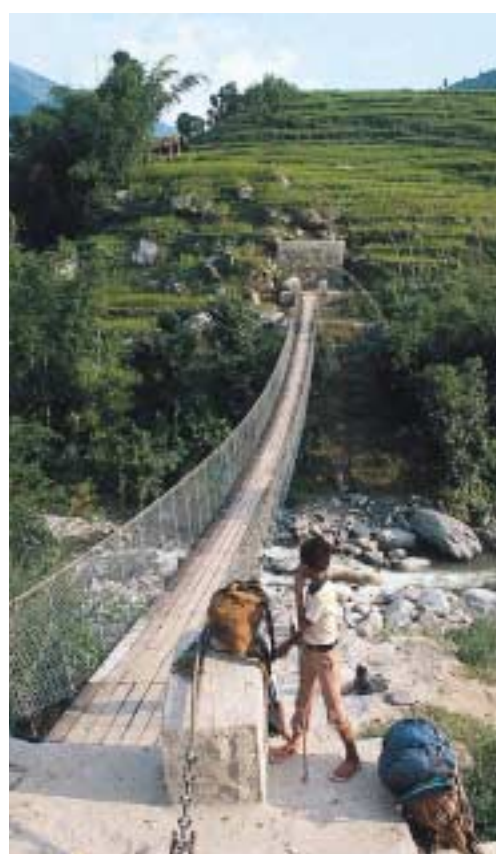
Tibetan saint Thangton Gyelpo, who was also called the Iron Bridge Builder, built many iron chain bridges in Tibet and neighbouring countries. Some of the bridges still exist today. (Courtesy F. Gaehwiler)

Suspended bridge in eastern Nepal. Modern bridges such as this one greatly facilitate transport and communication in the Himalaya. Unlike most traditional bridges, this one allows the passage of animals. (F. Gaehwiler)

Graphic depiction of a suspension bridge and a suspended bridge, the two most widely used types of construction for trail bridges in the Himalaya. (Courtesy F. Gaehwiler)

## Bridges for rural access in the Himalaya

For Buddhists, bridge building is a very beneficial activity; it means alleviating other people's obstacles. Thus, trail bridge building has a long tradition in the hills and mountains of the Himalaya. For centuries, narrow gorges have been crossed with simple log or rope/cane bridges, bamboo arch bridges, skilfully constructed cantilever bridges, iron chain bridges, and bamboo/cane bridges. Most of these traditional bridges could not be crossed by animals, had a limited span of less than 50 m, and very often had to be dismantled before the onset of the monsoon to prevent them from being washed away.



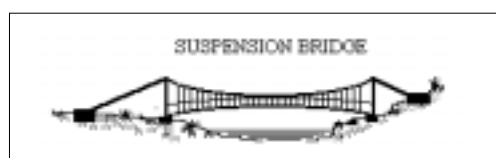
In the early 1960s, a Swiss NGO actively supported the construction of a few suspension bridges over Nepal's Marsyandi River. In the 1970s, this led to the Suspension Bridge Project, which pioneered a technology for suspended cable and suspension foot bridges, based on traditional local bridges. The Suspension Bridge Division (SBD) was created as the government

organisation responsible for trail bridge building. Similarly, Bhutan's Public Works Department initiated a country-wide pedestrian bridge construction programme in the 1970s. In the 1980s, the two trail bridge programmes started an intensive exchange of experiences, and the synergies led to the optimisation of technologies. A series of manuals helped build up local capacities in both countries, and streamlined the planning, survey, design, construction, and maintenance of trail bridges.

### Bridges in Nepal: an overall concept and privatisation

SBD was mandated to construct bridges on main trails of national or regional importance. Planning, survey, design, supervision of construction and maintenance were done by local technical staff, and all steel fabrication works and civil construction were contracted to private contractors. With the development and introduction of the Main Trail Concept, following an extensive main trail study, a rational basis for planning, monitoring, and decision making was established.

During the 1990s, bridge survey, design, and task implementation were successfully privatised, improving both efficiency and effectiveness. New funding mechanisms, such as ex-post financing and the introduction of construction turnkey packages have been introduced, significantly simplifying financial management and administration. These measures led to substantial reduction of overhead costs in relation to the overall project cost.





In the late 1980s, a maintenance concept for main trail bridges was developed. Over the years the concept, consisting of major maintenance and routine maintenance, has been gradually improved, and an illustrative instruction manual has been prepared. Major maintenance is executed in partnership with the districts through cost sharing, whereas routine maintenance is carried out under the bridge warden scheme: every bridge is assigned to a bridge warden.

Apart from the main trail bridges, there is tremendous need for local bridges. Several attempts were made to assess existing local bridge building know-how and enhance it where possible. In 1989, the pilot project Bridge Building at the Local Level (BBLL) was launched under SBD; the main objective was to “reactivate, promote and support people’s problem solving and self-help abilities for local bridge building”. Various support approaches and designs appropriate for local bridge building were developed



and tested in different districts. Following the encouraging pilot phase, BBLL gradually expanded its activities in terms of districts covered and bridges supported. Over the last 10 years, the project has proven that its basic concept for supporting local bridge building is effective and successful. Most important is a good, serious initiative on the part of the local communities.

#### **Bridges in Bhutan: intensive community involvement**

Bhutan’s Suspension Bridge Programme (SBP) has always been characterised by intensive community participation, from planning through implementation of construction work to routine maintenance. In contrast to the Main Trail Concept in Nepal, prioritising of bridge sites has been decentralised to the communities. The users of the future bridges are involved in



planning and bridge building from the very beginning.

Since the private sector has been quite weak, it was only involved in the fabrication of steel parts. Civil construction work was carried out by villagers under the supervision of technical staff from the respective districts. Planning, survey, design and overall supervision are still carried out by SBP staff. In the absence of private engineering capacity, and as a part of the government’s decentralisation policy, efforts are underway to enhance the capacities of technical district staff in order to decentralise survey work to the districts by 2002.

*Franz Gaehwiler, M.N. Lamichaney*

Traditional cantilever bridge near Wangdue Pongrang, Bhutan. Originally built in 1684, the bridge was rebuilt many times due to flood damage before it was finally washed away in 1968.

(Courtesy HELVETAS)

Transport of cables for the construction of a suspension bridge – a dangerous task which is usually carried out by porters due to the lack of motorable access.

(F. Gaehwiler)

#### **Status of trail bridge building in Nepal and Bhutan: number, size, and cost**

|  | Nepal  |       | Bhutan<br>SBP,<br>since 1984 |
|--|--------|-------|------------------------------|
|  | SBP    | BBLL  |                              |
| Number of completed bridges (total)                                    | 491    | 700   | 168                          |
| suspended  | 264    | 699   | 103                          |
| suspension   | 212    | 1     | 51                           |
| steel truss  | 15     | 0     | 5                            |
| other types  | 0      | 0     | 9                            |
| Average span of bridges (m)<br>(suspension and suspended types)        | 95     | 56    | 66                           |
| Average cost of bridges (US\$)<br>(suspension and suspended types)     | 29,900 | 6 000 | 13,700                       |
| Average cost per metre span (US\$)<br>(suspension and suspended types) | 315    | 100   | 206                          |

Explanation of abbreviations and acronyms: see main text.

*Ropeways are used as a cost-effective and environmentally friendly means of forest management and harvesting (cable logging) in many mountain areas world-wide.*

Ropeway securing the transport of passengers and heavy goods to a high-altitude copper mine in Irian Jaya, Indonesia. (Doppelmayr Seilbahnen AG)

## Ropeways for mountain tourism and development

In mountain areas, where the landscape is dissected by deep valleys and great differences in altitude have to be overcome, ropeways (cableways) can provide a cost-effective alternative to railways, roads, and bridges for ensuring public transport links to and from remote mountain areas, securing flows of basic goods, and assuring transport of local products including crops, animals, and bulk commodities such as timber and minerals.



The origins of ropeways go back to ancient times, as shown by Chinese ink paintings from the 3rd century BC. The invention of

the iron cable in the early 19th century and the age of industrialisation and bulk transportation led to a boom in ropeway development for the transport of goods. By 1910, over 12,000 large ropeways to haul raw materials and goods existed worldwide, including such gigantic installations as a 35 km ropeway for transporting gold ore in Argentina over an altitude of more than 3500 m. Most of these ropeways have now been replaced by roads

### 17 years of unflinching service – the Tashi-La ropeway, Bhutan

Inaugurated in 1983, the Tashi-La ropeway in Bhutan links the remote Kokota valley with the outside world. It ensures the export of timber, fuel-wood and agricultural products, and the import of consumer goods for the local communities. The ropeway has been operating without a major incident since its construction. Passenger transport was discontinued recently, pending a major overhaul. The ropeway, 5 km long over an altitudinal range of 1500 m, has a transport capacity of 800 kg and is run by a 65 hp diesel engine – running costs are thus minor. Maintenance, a critical factor in operation, has been in the hands of local residents for many years. They successfully run the ropeway as a private enterprise for the benefit of the mountain community. (Karchung Dukpa and Hansruedi Stierlin, courtesy HELVETAS).



### Ropeways – one of the safest means of transport

Global statistics have proven that ropeways are one of the safest means of transport – not only in mountain areas. With billions of passengers transported worldwide annually, there have been less than 300 casualties in the last 40 years.

(Source: Global Cableway Statistics 1999, University of Stuttgart)



and railways. Ropeways for passenger transport were first used in larger towns, forming part of the emerging urban public transport sector. San Francisco's cable cars, built around 1870, are reminiscent of this development; most other systems have since been replaced by tramways and buses.

### A key element in mountain tourism

In mountain areas, the great expansion of ropeways was linked to the emergence of winter tourism in the 1920s, and especially since the 1950s, when mass tourism gained momentum. There are now over 10,000 installations in over 100 countries worldwide, including a wide range of technical systems such as funiculars, cable cars, gondolas, and chair lifts. Most of today's ropeways are used for passenger transport in tourism, and are largely in mountain areas. Without ropeways, the development of the tourism industry in many mountain areas would not have been possible. One example is the tiny state of Andorra in the Pyrenees, which has over 70 ropeways and ski lifts, with a potential transport capacity of over 130,000 passengers per hour. These have been a key to making tourism the most important industry and to tripling GNP over the last 30 years.

**There are 10,747 ropeways and 18,142 surface lifts worldwide, most of them in tourist areas.**  
Total ropeways by region:

|                     |      |
|---------------------|------|
| Japan               | 3069 |
| USA/Canada          | 2519 |
| Alpine countries    | 3691 |
| All other countries | 1468 |

(Source: Global Cableway Statistics 1999, University of Stuttgart)

### Ropeways for development

Ropeways also have extensive potential in the developing world. Studies in Nepal suggest that ropeways are cost-effective in comparison with rural roads and bridges – and even with local trails and suspension foot bridges. The location, design, and construction of ropeways require a combination of skills, including those of transport economists and those of structural/civil engineers: the former to consider the economic costs and benefits, and the latter to identify and build the appropriate structure. If ropeways are to be sustainable, local communities should be

## Pros and cons of ropeways in mountain areas

### Points in favour of ropeways:

- Construction and maintenance costs for ropeways are lower than for railways and roads.
- Ropeways are much less susceptible to mountain hazards such as landslides, avalanches and flooding than roads or railways.
- Ropeways allow local communities to have greater economic control over trade and transport. Roads provide an easier entry point for outside economic interests.
- Ropeways are environmentally friendly; they consume less space than roads and create less air pollution.

### Challenges to consider in ropeway construction:

- Owing to their potential to open up inaccessible areas, ropeways can threaten fragile mountain areas, especially if related to mass tourism or extensive exploitation of mineral resources.
- Ropeways require goods to be loaded and unloaded from other means of transport.



The origins of ropeways date back to ancient times. This painting shows a ropeway powered by human force, drawn by a Japanese artist around 1250 AD. (Courtesy H. Dieter Schmoll)

responsible for their maintenance. A technical expert with a background in social development is thus desirable to advise on the mobilisation and training of local groups or individuals.

*H. Dieter Schmoll, David Seddon, Broughton Coburn*

Ropeway for passenger transport in Squaw Valley, one of the leading tourist resorts in the USA. The installation has a transport capacity of 4000 persons per hour. (GARAVENTA AG)



## Animal power: appropriate transport in mountain areas

In many mountain areas, animal power is still the most important means of personal mobility and local transport of goods. Communities are often connected to markets, health centres, schools, and government services by narrow tracks on which horses, mules, donkeys, yaks, llamas, and other animals can carry loads or be ridden. Mountain communities are often disadvantaged, with few income-generating options. Animal transport can be an affordable way to collect supplies, market produce, and engage in sustainable livelihoods. In developed countries, people are choosing animal power for its ecological benefits.

Pack ponies are used in many countries, including the relatively hot and humid mountains of Laos. (P. Starkey)



Donkey carrying fertiliser in Pakistan. One third of the donkeys in the world are found in the Asian mountains, notably in China and Pakistan and neighbouring countries. (P. Starkey)



### Appropriate technology with ecological advantages

Animals were once used everywhere for short- and long-distance transport. Now, motorised vehicles are used for long-distance transport where roads exist. Yet animal power is convenient and affordable for carrying small loads: water and fuel for household use; manure, fodder and crops on the farm; and crops from the farm to the market or main road. Animal transport complements long-distance motorised transport by providing local supply and distribution.

Animal power is a natural, renewable energy source. Animals consume local feed, reproduce, and supply valuable manure. Draft animals cause less pollution and environmental damage than motorised alternatives. Animal power is widely available in mountain regions, is generally affordable by rural people, and

helps develop local trade. It is labour-intensive and provides valuable employment, particularly in tourism.

### Advantages of different transport animals

Horses are often perceived as the most effective transport animals. They are used for riding, carrying and, where tracks or roads exist, pulling carts. In temperate climates and in remote mountain areas they have high economic and social importance, and they are often expensive. They require high levels of management and feeding.

Donkeys are increasing in importance in many places. Though smaller than horses, they are very hardy, reliable, and sure-footed. Donkeys are low-risk animals: cheap, good survivors, and seldom stolen. They are easily managed by men, women or children, and often



preferred for domestic and small-scale transport. In the highlands of Ethiopia, five million donkeys carry fuelwood, building materials, fodder, and goods.

Mules are bigger and stronger than donkeys, harder than horses, and very sure-footed. They are used for commercial pack transport and trekking. However, the need for cross-breeding means they are often in short supply and more expensive than horses.

Oxen are mainly used for tillage and pulling carts, and sometimes for riding and pack transport in humid mountain areas. Yaks, and crosses between yaks and cattle, are important pack animals in the Himalaya. Llamas carry small loads in the high Andes. Camels are used for transport in the mountains of Central Asia, the Sahara, and the Middle East.

### Recognising the importance of animal power

Few government officials consider the importance of animal power in the mountains. The topic is omitted from their training. As they may be unaware of key issues, there is a need to increase awareness of the benefits and possibilities of maintaining or expanding the use of transport animals to complement motorised transport.

Pack saddle technology can be simple. Good designs protect the spine, improve efficiency, and prevent animals from suffering. In areas where people overload animals, participatory programmes of education, supported by legislation and enforcement, are required. While cart technology is often overlooked in mountain areas, as riding and packing are more important, carts can provide valuable additional capacity for on-farm and village-to-main-road transport.

Many mountain regions have military significance, and pack animals have often provided armies in remote areas with reliable, all-weather, day-and-night transport of supplies. Outflanking by crossing mountains with animals proved as effective in the late 20th century as in previous eras, with donkey transport proving crucial in military campaigns in Ethiopia and Eritrea.

### The future: an important role for networks and supporting organisations

As road networks will remain limited in most mountain areas, feeder transport will continue to depend on human and animal power and all-terrain vehicles. In poorer mountain areas, sustainable livelihoods will continue to depend on animals for local supplies and market access. As men seek work in cities, the responsibilities



Woman with llama in the High Andes, Ecuador. In mountain areas with few employment opportunities, men seek work in cities and women are increasingly responsible for marketing and family transport. Animals provide a flexible and affordable option. Llamas are used for pack transport, carrying loads of about 20 kg. (P. Starkey)

of women for household transport will increase. In richer areas, the ecological and aesthetic advantages of animals will ensure their continued use. Eco-tourism, using horses and mules, is likely to become increasingly popular.

The remoteness of mountain regions means that users of animal transport find it difficult to exchange ideas and innovations with people in similar situations. Networks and supporting organisations can encourage the exchange of experience and help people collaborate to improve technologies and systems of use.

*Paul Starkey*

Mule carrying fuelwood in Turkey. Mules are often considered the best animals for mountain transport as they are strong, hardy and sure-footed. (P. Starkey)



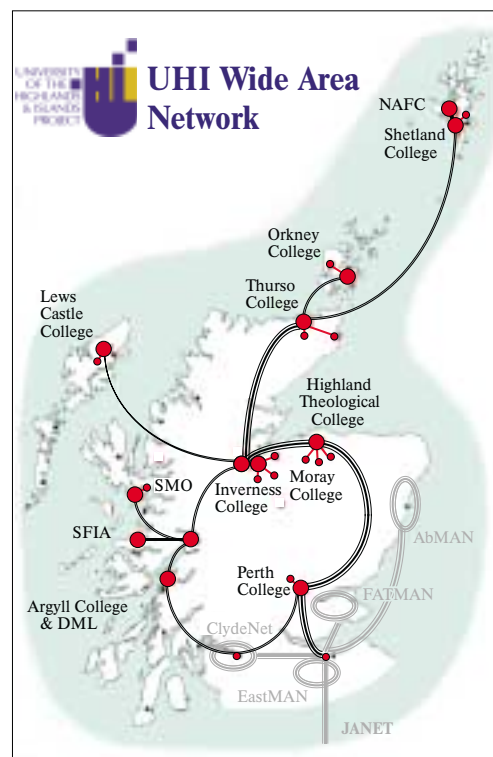


UHI's 15 academic partners and over 60 'learning centres' in small communities in northern Scotland are connected by a high-speed network which allows rapid communication using Internet, e-mail, videolink, and voice services. (Source: The University of the Highlands and Islands, Scotland)

In late 1999, the number of video conferences involving four or more sites of the University of the Highlands and Islands was almost as high as for all other universities in the UK combined. (The University of the Highlands and Islands)

## Using communications technologies to promote access for mountain people

Mountain people and organisations have many common characteristics. Among these is their isolation both from one another and from much of the rest of society. Another great challenge faced by mountain communities around the world is finding ways to reverse the 'brain drain' of talented young people. New economic opportunities and educational services created through modern communications technologies can be the key to responding to such challenges.



### New technologies help create a regional university

Most universities are in cities outside the mountains; even those in the mountains tend to focus on subjects which are academic and not directly relevant to sustainable mountain development. Through modern information and communications technologies to increase access to, and participation in, lifelong learning across northern Scotland, The University of the Highlands and Islands (UHI) explicitly aims to foster sustainable development and support diverse cultural and linguistic identities. The UHI partnership includes 15 academic partners, which deliver and support undergraduate and postgraduate courses and research, and over 60 'learning centres' in small communities.

Over five years, Mountain Forum has steadily added members and now lists over 2000 members in over 100 countries: 26% are mountain inhabitants, 68% are professionals working in mountains or on mountain issues, and 28% are visitors or users of mountains.

UHI courses focus on regional needs, attracting students interested in challenges facing dispersed communities with rich cultural histories and diverse natural resources. Eventually, Internet and video teaching will permit students to study for degrees from most of the academic partners and learning centres. Unlike most universities, most students are not school leavers; two-thirds are 'mature' students, over 26. Many have families and jobs, and have studied at university previously. Half study part-time, an option facilitated by the modular design of courses.

Video-conferencing, which allows people in different locations to see and speak to each other across any distance, is central to UHI's operations. While half of the video conferences are for teaching, the technology is vital for effective functioning; most committee meetings use this facility to save on travel time and costs. A key element is the library: resources at all academic partners can be identified.





tified and requested on-line via the UHI Intranet. Gradually, a dynamic learning environment networked across the Highlands and Islands, with links to learning communities beyond the region, is being created.

### **Mountain Forum – a global network for information sharing**

Mountain Forum was created in 1995 through the collaboration of non-governmental organisations (NGOs), universities, multi-lateral agencies, and the private sector. This rapidly-growing global network aims to catalyse global action towards equitable and ecologically sustainable mountain development and conservation through information exchange, mutual support, and advocacy. Taking advantage of the expansion of the Internet into even remote mountain areas, its services include discussion lists, an interactive website, and electronic conferences.

### **A 30% increase in sales thanks to the Internet**

Among the greatest potentials for economic development in mountain areas are high-quality products which can only be produced under specific local conditions. Yet producers are far from potential markets which, using appropriate packaging and delivery, can be anywhere. Internet marketing can be a cost-effective solution. For example, Dundonnell Smoked Salmon, operating from a small lakeside farm in the remote Western Highlands of Scotland, relies on its website to generate 30% of its sales. Over four years, the use of the Internet resulted in a 30% increase in sales.

Mountain Forum coordinates its activities through a global secretariat, a global information server node, and regional nodes for Africa, Latin America and the Caribbean, Asia and the Pacific, and Europe. The European Mountain Forum has regional sub-nodes, hosted by local NGOs. While English is the dominant language, communication in Latin America is in Spanish. In Europe, French and other regional languages are used widely.

Many people do not have access to the Internet, and available information may not be in languages which can be easily understood by those who require it. Consequently, the global and regional nodes provide information using more traditional media, e.g. printed documents, telephone, fax. Thus,

### **Mountain Forum: success stories in exchange**

Examples of successful transfer of experiences and information have included:

- snow leopard conservation in China, Mongolia, and Pakistan
- legal recognition of indigenous knowledge in Canada and the Philippines
- protection of sacred sites in New Zealand and Venezuela
- women's cooperatives in Greece and Mexico
- tourism codes of conduct in India and Peru
- protected trademarks for mountain products in France and Italy
- wildlife viewing micro-enterprises in Nicaragua and Uganda
- investment in water conservation in Bolivia and the USA
- community forestry legislation in Nepal and Switzerland

using diverse means, Mountain Forum facilitates dialogue and information exchange between mountain communities and decision-makers, giving mountains a home base on the Internet.

### **Niche marketing changes the economic landscape**

Until recently, the Deer Run Sheep Farm in the Appalachians, USA sold specialty fleeces through the local wool pool, which in 2000 offered only 20 c/pound. In 1997, Martha McGrath, the farm's owner, turned on a computer for the first time, joined e-mail lists and began posting notices on agricultural websites. She created her own website and joined a number of 'web rings'. Now she sells her fleeces directly to hand spinners throughout the USA and Canada, for an average of US\$8.00/pound; up to US\$16.00/pound for the best fleeces. By reaching her market directly instead of through middlemen, she has improved her economic landscape.

*Elizabeth Byers, Martin Price, Alejandro Camino, and Simone Nelson*

Small farm at Loch Torridon, Scotland. Modern communications technologies such as the Internet can help overcome the isolation of remote mountain communities, e.g. by providing access to educational services or markets for quality mountain products. (I. Sarjeant)





# Mountain energy and transport: challenges for the 21st century

Downstream interests have largely dominated energy and transport development in mountain areas. In a rapidly urbanising and increasingly globalised world, mountains continue to play an important role in securing transport links and providing energy for surrounding lowlands and urbanised areas. Providing services such as these often has negative impacts on mountain regions. It is critical that mountain communities benefit from the diverse energy resources available in mountain environments and the development of transport networks and other new means of communication. A careful balance between downstream interests and mountain interests is urgently required.

## Energy in mountains – the key issues

Mountains are vital sources of energy in very diverse forms, including physical and spiritual energy. Specifically, mountains and highlands are known for their extensive potential for hydropower generation, which is due to high gradients, relatively high precipitation and runoff compared to adjacent lowlands, and water stored as snow and ice. Even more electricity is produced downstream on rivers fed by mountain areas. Hydropower generation in mountains will increase as its huge potential, especially in developing countries, is tapped in the years to come.



Hydropower from mountain regions can help to move the world away from its present unsustainably high levels of fossil fuel use. (BKW-FMB Energie AG)

In mountain areas, the keywords associated with energy development are “decentralisation” and “small-scale”. Small-scale hydropower is particularly promising. There is extensive experience worldwide with this mature technology. It minimises high transmission costs in difficult terrain as well as social and environmental impacts and satisfies local needs. However, larger schemes may also be necessary to supply growing urban and industrial centres in mountains and downstream areas, and to reduce current high consumption levels of non-renewable energy such as fossil fuels, which are an important factor in global warming. At the same time, there is a danger that large-scale hydropower generation in mountains will sideline environmental and social concerns owing to growing demands for clean energy and the marginal position of mountains in decision making processes dominated by downstream interests.

For most mountain people, fuelwood is still the most important form of energy. Although the demand is increasing as populations grow, there are signs of hope: improved cooking devices can reduce fuelwood consumption, modified construction of buildings can significantly reduce energy needed for heating, and alternative energy sources can relieve pressure on wood resources. Solar and wind energy systems have considerable potential in mountains as stand-alone facilities. Initial investment is still too high for local communities, especially in poorer areas, but running costs are very low and the resources are unlikely to ever run out – good reasons to promote such systems in mountain areas.





Mt. Kenya, Africa's second highest mountain (5199 m) – a place of spiritual energy and worship in earlier times. (R. Brunner)

### Transport in mountains – the key issues

Mountains have benefited from transport development through increased employment and income opportunities, access to health, education and consumer goods, and exposure to the wider world. Access also increases opportunities for regional cooperation between mountain areas. Negative impacts – brain drain, overexploitation of resources, forest die-back, destruction of habitats, and disruption of local culture – must be mitigated by policies and regulations that consider local environmental and socio-economic aspects.

The development of transport infrastructure in mountains is technically demanding due to topography, climate, and the need for protection from hazards such as avalanches, landslides, and rockfalls. Engineering biology can help protect or restore fragile vegetation cover. All these factors increase the costs of constructing and maintaining roads, railways, and other means of transport in mountain areas. Roads will continue to be the main means of improving access to mountains in many parts of the world. In developing countries, labour-intensive road construction has shown great potential; the economic benefits of construction are largely retained within mountain areas in the form of local salaries, and there is less environmental damage than when construction is based on the use of heavy machinery. Specific technologies, such

as ropeways, suspension bridges, or air transport can provide links where railways and roads are not economical. Modern information technology can greatly improve linkage between mountain areas and the wider world. Animal transport, a cost-effective form of exchange integrated in local livelihoods, will remain important in many mountain regions.

### Four guiding principles for dealing with energy and transport in mountains

Adhering to the following principles will help to secure sustainable development of energy and transport in mountain regions:

- *Negotiate outcomes*

Pursue the principle of negotiated outcomes involving all stakeholders, explicitly

*Two billion people lack electricity, and demand for electricity in developing economies continues to rise. (Source: World Commission on Dams, 2000)*

### Costa Rica: compensating land users in mountains for economic and environmental services

In Costa Rica mountain forests help to generate one-third of the country's electricity and half of its drinking water, and provide habitats for many species of flora and fauna. Under the Forest Law of 1996, forest owners are compensated for economic and environmental services that their forests provide to society. The compensation system, funded by a tax on fossil fuels and payments from hydroelectric corporations, paid out US\$ 14 million to forest owners in 1997. 80% of the funds came from national sources, while 20% was generated by the international sale of carbon fixation services under the "Clean Development Mechanism". (Mountain Agenda 2000, José Campos and Julio C. Calvos)



Transcontinental road link across the Andes: the Paso de Jama section of the Corredor del Capricornio, at about 4000 m in northern Chile. (A. Schellenberger)



*100% accessibility in the Swiss Alps means that the nearest road is at one's doorstep. In the mountains of Ethiopia, it means that the nearest road is within one day's walk.*

including local mountain communities. Negotiation must provide for independent arbitration where necessary, and give similar weight to environmental, social, and economic aspects of development.

- *Share benefits through the principle of equity*  
Compensate mountain regions for services provided to society by sharing benefits that accrue nationally or globally. There is less need for additional external funding than for more equitable re-allocation of existing funds within countries.
- *Tailor development to mountain regions*  
Respect the specificities of mountain communities and environments by applying or developing appropriate and non-stereotypical technical solutions for the transport and energy sectors. The key issues are decentralisation, protection from natural hazards, and careful construction to avoid damage of fragile environments.

- *Build on existing facilities and experiences*  
Optimise use of existing facilities and institutions by improving their efficiency and effectiveness before creating new ones. Promote and enforce demand-side management, especially in well-developed mountain regions.

### **The challenges ahead...**

#### **... for local communities**

Mountain communities should be committed to the principle of sustainability in their management of local resources. They should be ready to participate in the development of energy and transport facilities that serve local needs. This may require the (re)establishment of local institutions to shape local opinion and secure ownership of installations. Taking advantage of improved access and communications technologies, mountain communities can greatly benefit from establishing links between themselves and creating regional institutions to enhance their political position. Local or regional communities can also substantially improve their standing through linkages with institutions in civil society at large such as NGOs and the media.

#### **...for national governments and authorities**

National authorities must formulate energy and transport sector policies based on realistic forecasts and acknowledgement of the need for mountain-specific approaches and technologies for transit, access, and energy generation. Modernisation should be pro-

### **Switzerland: royalties for mountain communities for water used in hydropower generation**

Switzerland's abundant water resources have been the backbone of the country's electricity supply for decades. Under Swiss law, hydropower exploitation is based on time-bound concessions. Facility owners pay a royalty to regional or local governments, which have sovereignty over water resources. In addition to royalties, an income tax is charged. In many mountain communes, water royalties and taxes on hydropower facilities are by far the largest source of revenue. In 1998, the State of Grisons in the Swiss Alps earned US\$ 75 million, or US\$ 400 per capita, from hydropower facility owners. (Swiss Federal Office for Water and Geology)



moted where it supports mountain people, and should take account of traditional forms of transportation and energy use, so as to transform rather than disrupt mountain livelihoods. National authorities should enforce safety standards for dams, roads, railways, and ropeways in mountains, environmental standards for minimum water flow and protection against natural hazards, and social standards such as full compensation when negotiated outcomes infringe on, or cause loss of, property rights for reasons of regional or national interest. Governments should introduce time-bound licences for hydropower facilities and water taxes to be paid by utilities to compensate mountain communities for the goods and services they render to society at large, such as electricity and recreation. Governments could use revenues from taxes on fossil fuels to promote the use of renewable energy and help mitigate negative impacts caused by access and transit facilities in mountain areas.

### ...for civil society and NGOs

Civil society and NGOs must be involved in negotiations to establish new projects. There is a need to see that authorities, facility operators, and private enterprises comply with approved policies, agreements and standards, to expose violations, and to lobby decision-makers, politicians, or the mass media to initiate remedial action. Civil society and NGOs can support appropriate projects and



Construction of scour checks in the side drain of a mountain road. Vegetation planted to protect against erosion can be seen on the slope. Construction and maintenance of roads and other infrastructure in mountain environments must be done carefully. It is technically demanding and generally more expensive than in lowland areas. (P. Hartmann)

approaches in energy and transportation development in mountains, and create awareness of best practices for infrastructure development by disseminating information about successful initiatives. They have a crucial role to play in supporting mountain community networks and unions, enhancing the position of mountain people in negotiation processes, and helping to prevent undesired outcomes and projects.

### ...for international organisations and the donor community

These institutions should only provide financial support to projects based on the principles of sustainable development, as a result of negotiated outcomes and agreed processes involving all relevant stakeholder groups, including local interests. Guidelines need to be established for supporting local

Girl collecting fuelwood in the Atlas Mountains, Morocco. In many mountain areas, fuelwood will remain the cheapest and most easily accessible source of energy for years to come. It can be made considerably more efficient with simple techniques such as improved stoves. (D. Maselli)

### Strengthening community control over mountain resources: Thailand's Northern Farmers' Network (NFN)

NFN was formed in 1995 in Chiang Mai, northern Thailand. It links upland and mountain communities from the four main river basins of northern Thailand – especially those with community forest practices – in order to strengthen local control over the use and management of natural resources, including river waters, which are threatened by dam and diversion projects for hydropower generation and irrigation for the benefit of downstream areas. In order to enhance its position, NFN has established links with national and international NGOs. (Source: TERRA: Watershed 5/No. 1/1999:58)



Man on horseback in Turkey. Traditional means of transport such as animals will remain important for carrying people and loads in many mountain regions.  
(P. Starkey)

*In the USA, the Internet is used by 26% of the population, in Africa by less than 0.1%. There are more telephone connections in Manhattan, New York, than in the whole of Africa.*  
(Nua Online Information, March 2000)

Remote village in the southern highlands of Eritrea. Improving linkage with the outside world can help improve living conditions in isolated mountain communities such as the one shown here.  
(T. Kohler)



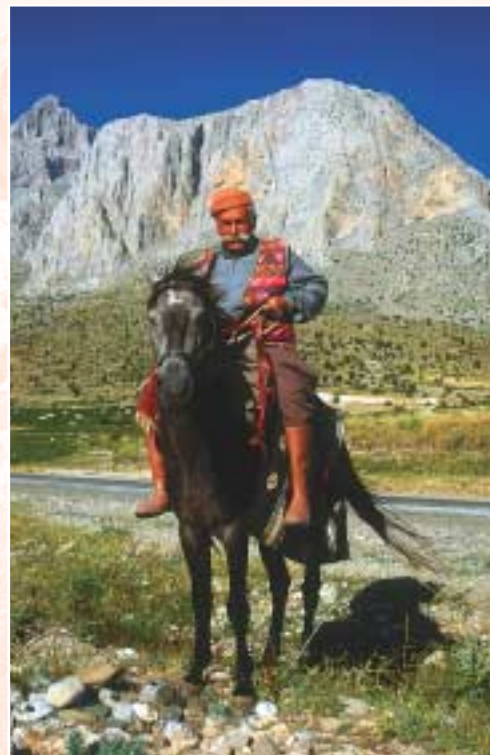
and regional networks and for agreements that promote regionally balanced development, including social and environmental standards, in the energy and transport sectors. International organisations and the donor community should support transboundary cooperation for the sustainable development of international mountain areas, e.g. with regard to transit corridors, watershed management, hydropower generation and electrification.

### **... for the private sector and professional associations**

Private sector enterprises have a responsibility to support development that includes environmental and social as well as economic considerations. Together with professional associations, these enterprises should develop voluntary codes of conduct for energy and transport development in mountain areas. They should comply with regulations and standards established by international and national authorities, train their staff and make executives aware of positive and negative impacts of transport and energy development in mountain areas, and abide by the provisions of anti-bribery conventions.

### **...for the scientific and research communities**

As demands for energy in all regions, including mountain areas, increase, there is an urgent need for innovation leading to more efficient use of existing technologies and to new technologies in energy and transport. Researchers should join forces with private enterprises, professional associations, and mountain representatives to develop real-



istic and acceptable solutions and test new devices and approaches. However, innovation is not limited to technology. The scientific and research communities can help formulate compensation mechanisms (water royalties) and quality labels (green electricity), or help define enabling incentives for new approaches and technologies. They can support policy makers in the formulation of a resource policy that gives priority to renewable resources.

The impacts of energy and transport facilities often remain poorly understood. Short-term impacts may differ substantially from long-term impacts. Monitoring of such facilities, including technical, socio-economic and environmental aspects, is essential. Monitoring and documentation provide valuable baseline material for informed decision-making relating to new projects, and also provide data for designing measures to mitigate the unresolved legacies of past projects.

### **2002 – and beyond**

The year 2002 is the International Year of Mountains. 2002 thus presents an excellent opportunity for further development of long-term collaboration between all the stakeholders concerned with energy and transport in and through mountain regions, to ensure that these key sectors benefit both mountain people and those dependent on mountain energy sources and transport links.





Painting of a village with a small hydropower plant, Nepal. Painted by a monk from the local monastery, the picture symbolises the integration of traditional culture and modern technology. The plant is at the bottom centre of the painting. (Courtesy ITECO)

---

# Mountains of the World: Mountains, Energy, and Transport

## **Coordinated by the Mountain Agenda (concept group):**

Thomas Kohler, Martin Price, Ulrich Lutz, with support from Andri Bisaz, Jean-Bernard Dubois, Roland Python, Urs Schaffner, Petra Schweizer-Ries, and Elizabeth Byers

## **Edited by:**

Martin Price, Thomas Kohler, Ted Wachs, Anne Zimmermann

## **Contributions on pages 4–7 and 46–50:**

Andri Bisaz, Thomas Kohler, Martin Price, Ulrich Lutz and Andreas Kläy, with additional contributions from members of the Mountain Agenda (concept group) and from reviewers.

## **Contributions on pages 8–45:**

- p. 8–9 Bikash Pandey, Winrock International Nepal. [bpandey@mos.com.np](mailto:bpandey@mos.com.np), Rudolf Rechsteiner, MP/President ADEV Energy, Switzerland. [info@rechsteiner-basel.ch](mailto:info@rechsteiner-basel.ch)
- p. 10–11 Audur Ingólfssdóttir, Environmental Research Institute, University of Iceland. [aingolf@hi.is](mailto:aingolf@hi.is)
- p. 12–13 Michael F. Baumgartner, MFB-GeoConsulting, Switzerland; Manfred Spreafico, Swiss National Hydrology and Geology; Heinz W. Weiss, Basler & Hofmann, Switzerland. [contact@mfb-geo.ch](mailto:contact@mfb-geo.ch)
- p. 14–15 Walter Zimmermann, ITECO Engineering, Affoltern a.A., Switzerland. [iteco@iteco.ch](mailto:iteco@iteco.ch)
- p. 16–17 Kamal Rijal, International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal. [krijal@icimod.org.np](mailto:krijal@icimod.org.np)
- p. 18–19 Robert Horbaty, ENCO Energy Consulting, Langenbruck, Switzerland. [enco@spectraweb.ch](mailto:enco@spectraweb.ch)
- p. 20–21 Kamal Rijal, ICIMOD, Kathmandu. [krijal@icimod.org.np](mailto:krijal@icimod.org.np) and Binayak Bhadra, ICIMOD, Kathmandu. [binayak@icimod.org.np](mailto:binayak@icimod.org.np)
- p. 22–23 Edwin Bernbaum, Sacred Mountains Program, The Mountain Institute (TMI), USA. [bernbaum@socrates.berkeley.edu](mailto:bernbaum@socrates.berkeley.edu)
- p. 24–25 Martin Price, Centre for Mountain Studies, University of the Highlands and Islands (UHI), Perth, UK. [martin.price@perth.uhi.ac.uk](mailto:martin.price@perth.uhi.ac.uk), based on an article by Charles S. Houston, Burlington, Vermont, USA. [chouston@zoo.uvm.edu](mailto:chouston@zoo.uvm.edu)
- p. 26–27 Anton Seimon, Dept. of Geography, University of Colorado, Boulder, USA. [seimon@colorado.edu](mailto:seimon@colorado.edu)
- p. 28–29 Peter Keller and Christian Heimgartner, IVT-Swiss Federal Institute of Technology, Zurich. [keller@ivt.baug.ethz.ch](mailto:keller@ivt.baug.ethz.ch)
- p. 30–31 Martin Grosjean, Swiss Federal Institute of Snow and Avalanche Research, Davos, Switzerland. [grosjean@slf.ch](mailto:grosjean@slf.ch), and Marcela Espinoza N., DIFROL, Ministerio de Relaciones Exteriores, Santiago, Chile
- p. 32–33 Udo Schickhoff, Department of Botany, University of Greifswald, Germany. [schickho@mail.uni-greifswald.de](mailto:schickho@mail.uni-greifswald.de)
- p. 34–35 Urs Schaffner and Ruth Schaffner, Schaffner Engineering Consultants, Oberhofen, Switzerland. [u.schaffner@swissonline.ch](mailto:u.schaffner@swissonline.ch)
- p. 36–37 Peter Hartmann, Hartmann & Sauter Engineering and Planning, Chur, Switzerland. [hartmann\\_sauter@spin.ch](mailto:hartmann_sauter@spin.ch)
- p. 38–39 Franz Gaehwiler, and M.N. Lamichaney, HELVETAS, Zurich. [franz.gaehwiler@helvetas.ch](mailto:franz.gaehwiler@helvetas.ch)
- p. 40–41 Hans D. Schmoll, Editor, Stuttgart, Germany. Fax ++49-711-76 44 26; Broughton Coburn, American Himalayan Foundation, Wilson, Wyoming, USA. [bcoburn@wyoming.com](mailto:bcoburn@wyoming.com) and David Seddon, Institute for Development Studies, University of East Anglia, UK. [J.D.Seddon@uea.ac.uk](mailto:J.D.Seddon@uea.ac.uk)
- p. 42–43 Paul Starkey, Animal Traction Development, University of Reading, UK. [P.H.Starkey@reading.ac.uk](mailto:P.H.Starkey@reading.ac.uk)
- p. 44–45 Elizabeth Byers, The Mountain Institute, Harrisonburg VA, USA. [ebyers@mountain.org](mailto:ebyers@mountain.org), Alejandro Camino, Mountain Forum, c/o ICIMOD, Kathmandu. [acamino@mtnforum.org](mailto:acamino@mtnforum.org), Martin Price (see p. 24–25), and Simone Nelson.

## **Boxes and quotations:**

Olivia Bennett and Siobhan Warrington of PANOS London. [oliviab@panoslondon.org.uk](mailto:oliviab@panoslondon.org.uk), provided the quotations on p. 4–7. All other quotations and boxes are credited directly, or were supplied by the authors of the contributions in which they appear.

## **Figures, graphics, tables, photo search:**

Lukas Frey, Kristina Imbach, Ulla Schüpbach

## **Cartography:**

Inset maps (p. 10–44) by Andreas Brodbeck, Institute of Geography, University of Berne

## **Reviewed by:**

**FAO** Food and Agriculture Organization of the United Nations, Rome  
**ICIMOD** International Centre for Integrated Mountain Development, Kathmandu  
**IGU** International Geographical Union  
**TMI** The Mountain Institute, Harrisburg (USA)  
**UNESCO** United Nations Educational, Scientific and Cultural Organization, Paris  
**UNU** United Nations University, Tokyo

## **Front cover:**

Dam for hydropower generation in the Swiss Alps (BKW-FMB Energie AG)

## **Back cover:**

On the road in the mountains of Pakistan (U. Lutz)



