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Thermal Insulation in High Mountainous Regions

A Case Study of Ecological and Socioeconomic Impacts in the Eastern Pamirs, Tajikistan

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As in many other high mountainous regions, local people in the Eastern Pamirs (Tajikistan) use biomass fuels, mainly teresken *shrubs, to heat their houses during the winter months. This overuse of already scarce natural resources results in serious land degradation. Since 2006, thermal insulation measures have been disseminated and financed through microloans. This case study analyzes the impacts of thermal insulation in Murgab, the main town in the Eastern Pamirs, where thermal insulation measures have been implemented in 159 households since 2008. Although clients are more interested in increased comfort than in fuel savings, according to quantitative data collected in 2010 and 2011, thermal insulation measures led to a 20 to 30% savings in heating energy on average. However, it is mainly better-off households that are aware of energy efficiency issues and willing to invest in thermal insulation. In contrast, poorer households are the main* teresken *users, but they rarely have their houses insulated due to a lack of awareness and a low ability to repay loans. Therefore, the approach to introducing thermal insulation has only had a small effect on* teresken *consumption until now.*

Keywords: *Energy efficiency; thermal insulation; biomass fuel;* teresken*; rebound effect; microloans; impact monitoring; Murgab; Pamirs; Tajikistan.*

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Introduction

The overuse of biomass fuel as a source of energy is considered one of the main reasons for land degradation. However, in many rural regions, households have limited access to electricity and fossil fuels, and, therefore, are dependent on biomass fuels to satisfy their urgent needs for energy for cooking and heating (OECD/IEA 2006: 419). In the scientific and development discussion about household energy efficiency, the improvement of cooking stoves has been widely addressed as a way to reduce indoor air pollution and the consumption of biomass fuel (Mäkelä 2008, World Bank 2011).

High mountainous regions with long, cold winters face an additional challenge, because most of the energy is used for heating rather than for cooking. With a warm winter room being a crucial livelihood asset, households spend a high percentage of their financial and time budget to acquire fuel for heating. Under such conditions, thermal insulation is considered to be the priority measure to reduce the loss of heat and the consumption of biomass fuel (Nienhuys 2012: 32).

This article presents a case study in Gorno Badakhshan Autonomous Region (GBAO) of Tajikistan, where the thermal insulation of private houses financed through microloans has been introduced by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, commissioned by the German Ministry for Economic Cooperation and Development. To convey important lessons learned that are relevant to the transfer of this approach to other high mountainous regions, the article outlines some of its strengths and shortcomings. It analyzes the demand for thermal insulation, the saving of heating energy, and the impact on the consumption of biomass fuel. The study focuses on Murgab, a town in the eastern part of GBAO at an altitude of 3600 masl (Figure 1), which is characterized by a high concentration of households that are clients of the thermal insulation program.

Thermal insulation in Murgab

Murgab (38°10′6″N; 73°57′51″E) has approximately 7000 inhabitants and 1500 households (Kreczi 2009). The landscape is characterized by wide, flat valleys. The climate is extremely arid and cold, and the short growing period and lack of water enable only sparse vegetation. Mainly *teresken* shrubs (*Krascheninnikovia ceratoides*) survive these difficult conditions and stabilize the soil and serve as fodder for wild animals and livestock (Domeisen 2002: 19–21; Hergarten 2004: 5–6). In Soviet times, the growth of the town was driven by the supply of fossil fuels almost free of charge, which encouraged inhabitants to build large houses without paying any attention to energy efficiency. This

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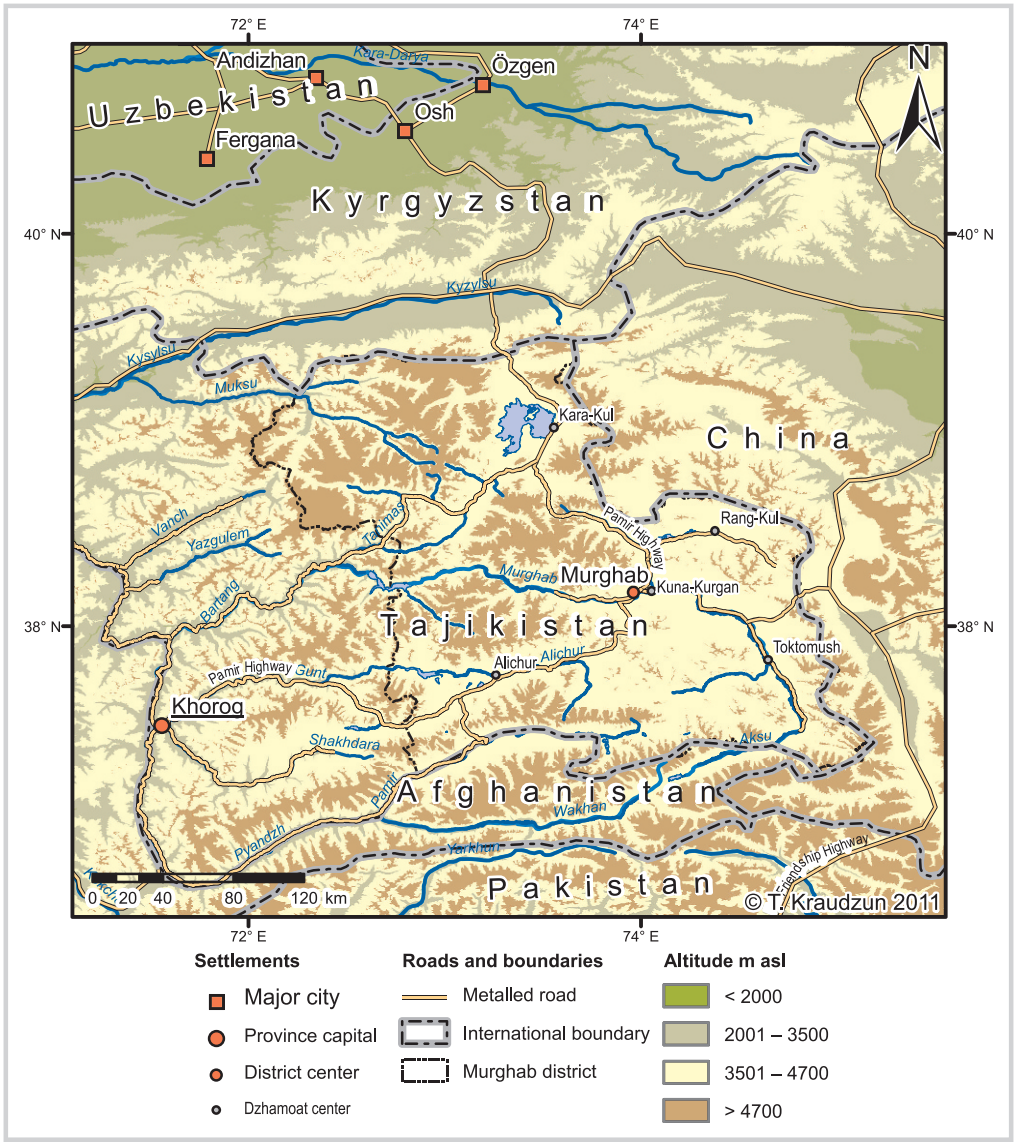
FIGURE 1 Murgab with its about 7000 inhabitants is the only major settlement on the high plains of the Eastern Pamirs. The urban centers of Khorog (Tajikistan), Osh (Kyrgyzstan), and Kashgar (China) are each more than 300 km away and accessible only via high mountain passes. (Map modified from Kraudzun 2012: 92)



supply came to an abrupt end with the breakdown of the Soviet Union in 1991. People had no other choice but to use the only locally available energy source, *teresken* shrubs (Figure 2), which has led to significant land degradation around human settlements (Droux and Hoeck 2004) in addition to overgrazing of winter pastures (see the article by Vanselow et al in this issue).

GIZ started to work in the field of thermal insulation by insulating a school in the village of Chechekty (20 km north of Murgab) in 2006. In 2007, a handful of private houses were insulated in Chechekty and Murgab by focusing on the insulation of ceilings and floors with locally available natural materials. Since then, thermal insulation measures have been implemented in 407 houses all over GBAO, including 159 in Murgab. Four key innovations have taken place:

1. It soon became clear that interested households rarely had sufficient financial resources for an investment such as thermal insulation. Therefore, in 2007, a microloan organization was involved and started offering financing to interested households for the necessary materials.
2. Carpenters in the province capital of Khorog have been trained in producing double-glazed wood-frame windows and hermetic doors since 2009. A craft workers' cooperative was established in 2010.
3. Because most heat is lost through thermal radiation, reflective foil has been used in addition to natural insulation materials since 2010.
4. There were significant problems with clients who used the microloan for other purposes than thermal insulation or who poorly implemented the thermal

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FIGURE 2 On the arid high plains of the Eastern Pamirs around Murgab, dwarf shrubs form the only vegetation. (Photo by Christoph Wiedemann)

insulation measures. Therefore, a new system of in-kind loans was introduced in 2010. The microloan organization provides wooden construction elements and insulation materials, and coordinates trained construction workers and transport. Clients reimburse the equivalent of these products and services in cash as they would a standard loan.

By 2011, the production of double-glazed wood-frame windows and hermetic wooden doors was managed by the crafts cooperative Zindagi, based in the provincial capital, Khorog. The microloan organization Madina va Hamkoron offered technical consultation and provided in-kind loans of up to US$ 500 for thermal insulation, and required reimbursement within 1 year, at a comparatively low interest rate of 2.5% per month. Two teams of construction workers trained in properly installing wooden constructions and insulating ceilings, floors, and walls were working in Murgab and received orders from Madina va Hamkoron (see Fabian et al 2010) (Figure 3).

Methodology

The following study is based on quantitative and qualitative data. In spring 2010 and 2011, the impact of thermal insulation on fuel consumption and living comfort was investigated by staff of the GIZ project (Dmitrieva 2010; Salzmann 2011). Quantitative interviews were conducted in households that had insulated their winter room the year before (13 of 33 households in 2010, 10 of 54 households in 2011) to compare the situation before and after insulation. The household heads drew seasonal calendars and estimated or measured the amounts of different types of fuel (coal, manure, *teresken*, and firewood), which were then translated into energy units (megajoules). Results may be biased by subjective assessments of the interviewees, who often could not exactly remember the amount of fuel and used nonstandardized measurement units. Apart from this, varying climatic factors make it difficult to isolate the influence of thermal insulation on energy consumption. Therefore, in 2011, the monitoring also included a control group that consisted of one randomly selected neighbor household per interviewed client household.

To gain a better understanding of some unexpected results, in August 2011, nonstructured qualitative interviews were conducted by the authors of this study with 9 client and 9 nonclient households in Murgab and Chechekty, which focused on socioeconomic aspects, fuel consumption patterns, and attitudes toward thermal

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FIGURE 3 Construction workers in Murgab are installing a hermetically closing wooden door produced by carpenters in Khorog. (Photo by Rustam Zevarshoev 2010)

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insulation. In addition, key informants (staff of the GIZ project and of the microloan organization, craft workers, and officials in Murgab) were interviewed.

Demand for thermal insulation

According to the microloan organization Madina va Hamkoron, the number of households in Murgab that took a microloan for thermal insulation steadily increased: 26 in 2008, 33 in 2009, 54 in 2010, and 40 in 2011. In 2011, the number of applications (102) was much higher than the number of actual clients. The demand is no longer the result of direct marketing efforts but rather of self-sustaining dissemination of information. Usually, satisfied clients create interest among neighbors and relatives by showing the insulation measures to them and telling them about the positive effects.

The maximum amount of the microloan (US$ 500) often does not allow complete insulation of the winter room. Therefore, decisions about the measures to be implemented are driven not only by technical but also by financial feasibility. However, some clients take additional microloans in subsequent years and insulate their winter rooms in several steps. Clients perceive the increase in inside temperature during winter as the primary advantage of thermal insulation and fuel savings as secondary. In 2010, 12 of 13 interviewees answered that it had become warmer inside their winter room, whereas only 6 interviewees highlighted that they had consumed less fuel.

Many clients are particularly enthusiastic about the double-glazed wood-frame windows (Figure 4). They are considered to make the room brighter, give the house a more beautiful outward appearance, and prevent dust passing through. As the only thermal insulation measure that is visible from the outside, the wooden windows also play a role as an "eye-catcher": when applying for a microloan, new clients usually want to buy a new window. Only during further consultation they are persuaded to implement more comprehensive thermal insulation measures.

A mapping of client households by key informants has clearly demonstrated that neither geography nor ethnicity has a significant influence on the demand for thermal insulation. Instead, socioeconomic status appears to be the main influencing factor. An analysis of data collected by Madina va Hamkoron about its clients in 2009 shows that they had an average monthly income of US$ 255, which is significantly above the average income of Murgab households of US$ 183 (Kreczi 2009: 50). The mapping of client households by the local representative of Madina va Hamkoron also indicates that, in 2010, they mostly belonged to the middle and upper strata of Murgab society, which can easily be explained:

1. When selecting clients, the microloan organization has to consider the ability of the clients to repay the loan, which makes households without sufficient income ineligible.
2. Many poorer households fear the obligations related to microloans and do not even consider applying.
3. Poorer households also usually have little awareness of energy efficiency and thermal insulation (see also Mirshakarov et al 2009).

The project approach has made it possible to reach households that have enough income to repay a microloan. Several applicants, clients, and key informants have highlighted the fact that the offer is particularly attractive due to its comprehensiveness, which combines quality wooden constructions ready for immediate installation, insulation materials, and a qualified workforce with a financing mechanism. However, because the approach is based on market mechanisms, it fails to attract poorer households.

By 2011, some 10% of households in Murgab town had taken a microloan for thermal insulation. The demand is much higher than in the Western Pamirs (1.5% in 3 districts) for 2 reasons:

1. When considering the high altitude, long heating season, and extremely cold winters, keeping the winter room warm is a survival issue, and thermal insulation makes a huge difference in living comfort.
2. Due to the remoteness of the region and the sparse vegetation, households in Murgab spend a high percentage of their household income on fuel (imported coal, *teresken,* and manure transported over long distances). In contrast, villages in the Western Pamirs are close to floodplain forests (providing firewood) and pastures (providing manure). Therefore, the financial incentive for saving energy is stronger in Murgab.

Key informants estimated that 30 to 60% of Murgab households were both willing and able to finance thermal insulation measures. Some households from villages in Murgab district (14,000 inhabitants, Kreczi 2009: 17) started applying for microloans to implement thermal insulation measures in 2011. However, the microloan organization is not yet ready to respond to this demand due to difficult logistics in the remote area and limitations in its organizational capacity and microloan portfolio.

Results of thermal insulation

In the framework of the project Habitat Improvement in the Hindu Kush, the Mountain Societies Development Support Program (MSDSP) comprehensively insulated corridors and classrooms in several schools in Murgab district in 2010 by using technologies similar to those disseminated by Madina va Hamkoron. Comparisons of an insulated and a noninsulated classroom of the same

FIGURE 4 The new wooden windows are double glazed and hermetic. In the past, many windows were only single glazed, had broken glass, and were covered with plastic foil during winter to reduce the loss of heat. (Photo by Stefan Salzmann, 2010)

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size showed that, under experimental conditions, approximately 40% of the heating energy was saved (MSDSP Murgab 2011).

On average, the 13 client households interviewed in 2010 had saved 26% on heating energy compared with the season before thermal insulation, whereas the 10 client households interviewed in 2011 had saved 22%. A comparison with the control group interviewed in 2011 gives a similar result. The 10 households with thermal insulation had consumed on average 31% less heating energy than the 10 households without thermal insulation. All in all, the available data indicate that the thermal insulation measures led to a reduction of energy consumption by 20 to 30%, which is significantly less than the 40% recorded in the MSDSP test, which can be explained by several factors. First, due to the maximum amount of the microloan, winter rooms usually had only been partly insulated. Second, the so-called rebound effect played a significant role, which has often been observed in similar contexts: "Many energy efficiency improvements do not reduce energy consumption by the amount predicted by simple engineering models. Such improvements make energy services cheaper, so consumption of those services increases" (Sorrel 2007: V). Almost all interviewed clients recognized that, after thermal insulation, it was warmer in their winter room than before. Obviously, the gains in energy efficiency were not completely invested in a reduction of energy consumption but also were used to reach a more comfortable living room temperature.

Finally, one household in Murgab in 2010 took an exceptionally large loan to install 2 double-glazed windows and to insulate the floor and the ceiling. In spite of the almost comprehensive insulation, energy savings remained relatively low (11%). Asked about the reasons, the family answered: "It was so warm in the room—we had the windows open every morning until noon, otherwise it would have been too hot" (Salzmann 2011: 8). In spite of thermal insulation, they had not changed their habits but had overheated the room and consumed almost the same amount of fuel as before. Insufficient awareness, a slow change of behavior, or insufficiently adjustable stoves may also contribute to low savings in heating energy in other cases.

There are clear indications that the above-mentioned household is a rather extreme case. Before thermal insulation, 9 of 10 client households interviewed in 2011 had heated continuously during daytime. After thermal insulation, 8 of these households had reduced heating frequency and used the stove only 2 or 3 times a day. This is certainly due to the increased stability of temperature. The client households interviewed in 2010 and 2011 clearly indicated that heat was kept inside the room for a much longer time after firing the stove (an average of 1.3 hours before thermal insulation and 3.3 hours after thermal insulation).

Teresken consumption

The role of *teresken* as the main energy source, and the negative effect on pastures of its overuse, has often been highlighted in academic literature (Domeisen 2002; Zibung 2002; Droux and Hoeck 2004; Breckle and Wucherer 2006; Hoeck et al 2007). The average annual *teresken* consumption per household in Murgab district has been estimated at 7900 kg (Droux and Hoeck 2004: 149).

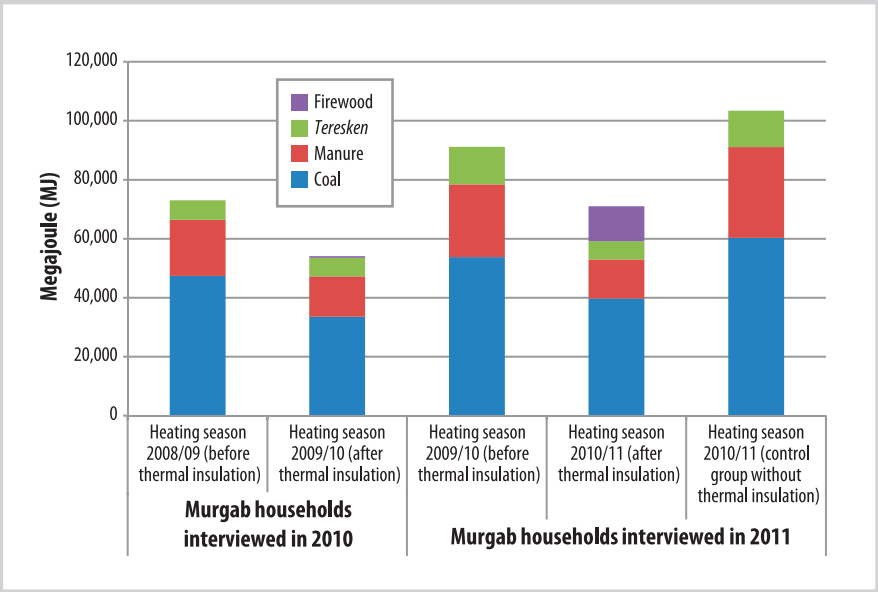
When it comes to the client households in Murgab town, the monitoring data show that on average they consumed only 1150 kg of *teresken* per heating season before thermal insulation (Figure 5). Significant quantities of coal imported from Kyrgyzstan and China had become available around 2005. Murgab inhabitants consider coal to be a much better heating fuel than *teresken*. However, coal has to be bought on the market and is perceived as expensive. *Teresken*, in contrast, can easily, although illegally, be harvested by the family members themselves, which requires financial outlays only for transport. Therefore, contemporary fuel consumption patterns in Murgab are closely related to the socioeconomic situation of households.

During the qualitative interviews and the drawing of seasonal calendars in August 2011, a clear picture of this interdependency emerged (see also Mirshakarov et al 2009; Förster et al 2011: 311–312):

1. **Better-off households** with sufficient financial resources buy most of their fuel on the local market. For heating in winter, they prefer long-burning fuels such as coal (US$ 0.15 per kg) and manure (US$ 0.04 per kg). The quickly burning *teresken* (US$ 0.15 per kg) is used only for lighting the fire. In summer, however, all households primarily use *teresken* and manure for cooking and baking. For this purpose, coal is not an economic option because it provides a long-sustained heat, which is unnecessary in summer. A small but increasing percentage of these households uses electric or gas stoves for cooking in summer.
2. **Poorer households** usually cannot afford to buy fuel (Figure 6). Members of these households spend every second or third day harvesting *teresken*, either in the mountains close to the settlement (individually) or in the high plains at a distance of some 30–70 km (in groups with a truck). To pay for fuel for the truck, they sell part of their harvest at the local market. If they own livestock, they also have manure available at low cost. They buy coal on the local market only when extra money is available.

According to rough estimations by key informants, approximately 50% of households in Murgab town have enough financial resources to buy most of their fuel at the local market. The other households mostly depend on *teresken*, which they harvest themselves. In the village of Chechekty, only some 10 to 20% of the households get

FIGURE 5 The average energy mix of client households before and after thermal insulation. In addition, a control group of households without thermal insulation was interviewed in 2011. (Graph based on monitoring data from Dmitrieva 2010 and Salzmann 2011)



sufficient manure from their own livestock or can afford to buy coal.

Almost all client households can afford to buy higher-quality fuel and are less dependent on *teresken*. Because they mainly save on expensive heating fuels (coal and manure) through thermal insulation, their investment quickly pays off. In contrast, poorer households use mostly *teresken* because they cannot afford higher-quality fuel. Because they do not spend much money ("only" their time) to acquire fuel, thermal insulation would hardly pay off for them financially. Client households use *teresken* mostly for lighting the fire rather than for heating. In winter 2010–2011, 9 client households in Murgab were each provided with an energy-efficient heating stove and 3 m^3 of firewood from sustainably managed floodplain forests in the Western Pamirs. In these households, *teresken* consumption decreased significantly and was compensated by the additional firewood (see Figure 5). This indicates that firewood is regarded as a substitute for *teresken*, which has been confirmed by several interviewees. If dry firewood were delivered to Murgab and the prices were similar to those for *teresken*, then these households would clearly prefer firewood both in winter and in summer, and thereby reduce their *teresken* consumption. However, they belong to the medium and upper strata of Murgab society, and paying for firewood would hardly be an option for poorer households.

Conclusion

The story of thermal insulation in Murgab is far from finished, but it has already provided important conclusions and lessons learned:

- Demand depends heavily on climatic conditions and fuel consumption patterns. The more people suffer from long, cold winters, and the more financial resources they spend on heating fuel, the more interested they are likely to be in thermal insulation.
- The effect on energy savings is lower than under ideal experimental conditions due to additional influential factors. However, thermal insulation does yield significant energy savings (20–30%) and does increase comfort, effects that can be increased by using improved cooking and heating stoves.
- The use of microloans as a market mechanism for dissemination, the focus on high quality, and the design of a comprehensive service package have triggered a self-sustaining demand for thermal insulation in Murgab, which is expected to involve about half of the households in the town during the coming years.
- The impact of thermal insulation on *teresken* consumption is rather small, because the main *teresken* users have not participated due to a lack of awareness and financial resources. This poses a dilemma for development agencies. To reduce *teresken* consumption, the main *teresken* users, the poorer households, need to be involved. But, in the short term, this is only possible by subsidizing thermal insulation, which might disturb the successfully established market mechanisms. The low awareness of poorer households and the low financial benefits for *teresken* users are additional challenges.

Recommendations

Further research is desirable on fuel consumption patterns and the potential demand for thermal insulation

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FIGURE 6 In Murgab town, it is mainly poor households that dig out *teresken* shrubs and fire them in the stoves for heating and cooking. (Photo by Stefan Salzmann, 2010)

by poorer households and households in the villages that surround Murgab. Thermal insulation can only be part of an integrated strategy to solve the energy crisis in the Eastern Pamirs. In addition, the provision of alternative fuels (firewood, coal, gas, solar energy, and hydropower) and the dissemination of energy-efficient technology (heating and cooking stoves for winter, cooking stoves for summer) are necessary.

In the end, the problem of overusing *teresken* is mainly related to poverty. It can only be solved if the poorer households are able and willing to spend money on alternative fuels and/or invest in energy efficiency. Any comprehensive strategy needs to tackle the root causes by investing in rural development, social infrastructure, and poverty reduction. Once awareness about energy efficiency has sufficiently grown, incentives for poorer households to invest in thermal insulation might be developed and piloted, for example, a public investment program or subsidized microloans for households defined by participatory poverty assessment, but care should be taken not to distort market mechanisms. Mere enforcement of the legal prohibition of *teresken* harvesting is unrealistic under the socioeconomic, political, and geographic conditions of the Eastern Pamirs.

The case of Murgab shows that it is possible to create self-sustaining and increasing demand for thermal insulation through market mechanisms, even if a complex approach with 4 complementary elements, technical consultation, supply of material, installation and insulation services, and a financing mechanism, has proved to be necessary. This approach may be transferable to other high mountainous regions with long, cold winters and fuel scarcity. In such cases, dissemination strategies should not only focus on saving fuel resources but also should use the arguments of increased living comfort and better aesthetics. Dissemination should be initiated in regional centers due to their higher potential demand and lower transaction costs. Awareness building on efficient heating, use of fuel, and ventilation should not be forgotten, in addition to the technical measures.

This approach has the potential to significantly reduce natural resource use. However, at least in the short term, market mechanisms insufficiently involve poorer households, which tend to be the main users of natural resources. To what extent they can succeed in doing so, in the long term, still needs to be investigated.

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