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Combating Energy Poverty in Mountainous Areas Through Energy-saving Interventions

Insights From Metsovo, Greece

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An increasing number of people find it difficult or even impossible to ensure adequate coverage of their energy needs. This situation, defined as energy poverty, is one of the results of the global energy crisis. Mountainous areas are especially vulnerable to energy poverty because their thermal energy needs are especially high and their economic environment is not a particularly prosperous one. We studied ways of reducing conventional fuel use and thus restricting the risk of energy poverty in Metsovo, a Greek mountain town. Given the special characteristics of energy consumption in the area and its energy potential, several alternative scenarios for saving energy in the town of Metsovo were constructed. The economic performance of the alternatives and their contribution to combating energy poverty were assessed. It was shown that utilizing locally produced biomass and applying energy-saving measures can bring households below the "energy poverty limit." Moreover, dependence on diesel oil and electricity for heating purposes can be reduced to a very low level by applying financially viable energy practices. The case of Metsovo shows that the establishment of an appropriate framework of sustainable energy policy in mountainous areas can bring about significant environmental, social, and financial benefits. The general objectives of the energy strategy of the European Union, as well as its efforts to combat energy poverty, can be significantly supported by the rich renewable energy potential of its mountainous areas, which is well illustrated by the example of Metsovo.

Keywords: *Energy poverty; biomass; energy saving; energy efficiency; renewable energy potential; Greece.*

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Introduction

Energy production at the global level is based mainly on nonrenewable sources. As their name implies, these sources are finite and exhaustible. Economically viable deposits of fossil fuels are becoming rare at the same time that global energy demand is increasing. It is estimated that global energy consumption in 2025 will be almost 30% greater than in 2007, and 80% of it will be based on fossil fuels (EIA 2010). The impacts of this situation are multidimensional: Environmental, economic, social, and political problems emanate from continuously increasing use of fossil fuels.

Energy poverty is one of the most important issues related to the global energy crisis. There are many approaches to energy poverty. A comprehensive description is contained in an opinion of the European Economic and Social Committee (EESC), published in 2011 (p. C44/54):

> *Energy poverty occurs where a household finds it difficult or impossible to ensure adequate heating in the dwelling at an affordable price … and having access to other energy-related services, such as lighting, transport or electricity for use of the Internet or other devices at a reasonable price.*

There is no standard quantitative definition of energy poverty. However, an approach that is often used is the following: If a household spends more than 10% of its annual income for energy, it is considered as energy poor (Walker 2008). This "energy poverty limit" was first introduced in the United Kingdom.

The impacts of energy poverty can be particularly negative. Premature deaths from indoor air pollution due to wood or coal use in poor households are the sixth largest health risk factor in developing countries (Sagar 2005). According to the United Nations, by 2030 deaths caused by energy poverty will be more than premature deaths owing to malaria or HIV if no action is taken (Lavelle 2010). Hence, several national and international organizations have become concerned about this problem. In 2010 the EESC proposed that combating energy poverty should be a new social priority within the European Union.

Increase in fuel prices is one of the main factors that intensify energy poverty, although this is virtually inevitable as the result of scarcity of fossil deposits, unstable tax policies, and inefficiencies in the function of the liberalized energy market (Bahce and Taymaz 2008; EESC 2011). Thus if no action is taken the problem will intensify as a result of the global energy crisis. Improving energy efficiency and promoting renewable sources of energy are the basic steps in combating energy poverty.

Mountainous areas have common characteristics that make them highly vulnerable to energy poverty. Many mountain economies are not particularly robust (Funnell and Parish 2001), mountain settlements are usually far away from major energy production centers, and thermal energy needs in mountain areas are significantly greater due to cold climatic conditions.

Especially in Greece, mountain communities are threatened by both the global energy crisis and the economic crisis. Between December 2010 and February 2011, incidents of illegal logging were recorded in mountainous areas of Greece (Peklaris 2010), as many people were unable to afford the cost of diesel oil and desperately sought for ways to cover their thermal energy needs. Such occurrences, following energy poverty, are common in developing countries (Foerster et al 2011), and it is quite worrying that they are also beginning to appear in the European Union.

There is a considerable lack of studies on energy-saving potential in mountainous settlements in Greece, as well as on the issue of energy poverty in mountainous Greece. The present study is one of the first attempts to compensate for this lack. Its main objective is to highlight the positive effects of energy saving in cutting the risk of energy poverty in mountainous Greece. The mountainous town of Metsovo (39°46′13″N; 21°11′02″E) was used as a case study (Figure 1). Metsovo is situated in the northern Pindos mountain range and lies at an altitude of 1100 m. It has about 3000 inhabitants, living in 750 households. Although it has a rich renewable energy potential, Metsovo is vulnerable to energy poverty.

Mountainous regions, according to EUROMONTANA, "are an ideal area for reducing energy consumption while maintaining a high standard of living" (2010: 4). Bearing this in mind, we have attempted to show that reducing fuel consumption should be a basic part of mountain energy policy. The current economic crisis threatens the standard of living in Greece, and in Metsovo expenses to meet energy needs are an especially high demand on people's income. Therefore, exploring energy-saving possibilities is necessary in order to preserve positive development perspectives in the area.

Methodology

The improvement of a building's energy performance is based on analysis of its energy consumption and a techno-economic assessment of available energy-saving solutions. In order to explore the possibilities for reducing energy consumption in Metsovo and thus reducing the risk of energy poverty in the town, the methodology used for a single building was generalized.

More specifically, the methodology included 5 steps:

1. *Collection and analysis of statistical data.* The data analyzed included the thermal and electrical energy consumption of the households, according to the Greek Energy Information System, and the characteristics of the buildings, according to the Hellenic Statistical Authority.
2. *Field survey related to the energy consumption of the households.* The survey aimed to define detailed characteristics of energy consumption in the residential sector (energy systems used, required fuel quantities, technical and geometrical characteristics of the residencies, etc) and was conducted on the basis of personal interviews in 2010. The sample included 200 households. At a confidence level of 95%, the margin of error of the survey is 5.81%, taking into account that the population (number of households) is 750.
3. *Thermal imaging of 90 houses.* The survey aimed to define weaknesses in the shell of buildings that lead to thermal losses. It was conducted between February and April 2011. The sample included houses in 4 age categories (before 1970, 1971–1985, 1986–1995, after 1996). The houses in the same age category present similar technical characteristics and energy performance.
4. *Formation of alternative scenarios for reducing energy consumption.* Five scenarios of different economic and technological intensity were constructed. The alternatives include energy-saving interventions, biomass, and solar energy utilization. In order to estimate the impacts of the alternatives on energy consumption, a "model house" was created for each age category, to which the energy improvement interventions were applied. Following the data analyzed in the first step, the model house was considered to have area and volume equal to the corresponding average sizes of the buildings belonging to the same age category. The technical characteristics of the "model house" were estimated according to both the statistical data and the field surveys.
5. *Technical and economical assessment of the alternatives.* In order to assess the financial performance of the alternatives, a feasibility study was conducted. The feasibility study was based on cash-flow tables, which include the financial benefits, the required investment costs, and the operation and maintenance costs for each alternative. Moreover, the contribution of the alternatives toward combating energy poverty was estimated, as well as environmental performance.

The central idea behind this study is to apply a methodology followed at a small-scale level (single

FIGURE 1 View of the town of Metsovo. (Photo by Nikolas Katsoulakos)

buildings) to a large-scale level (entire town). It was applied for the first time in mountainous Greece. The main advantage of this procedure is that it can provide quick and reliable estimates of the effectiveness of several "green" energy practices. Moreover, the accuracy of the results is far greater than the estimates currently available at country level. This allows for priorities for regional energy strategies to be set. Therefore, this methodology can be a useful tool for policy makers in mountain settlements to identify pathways to combating energy poverty.

Metsovo energy profile

The cold climate in the area around Metsovo results in high thermal energy demand, which is significantly greater than in areas at almost the same latitude but at lower altitudes. The mean annual temperature is 10°C, and the average annual rainfall is as high as 1473 mm.

Heating degree-days are summations of the differences between the average daily temperature and a base temperature, usually considered to be 18.3°C. They are derived from temperature measurements. The thermal needs of a building structure at a given location are directly proportional to the number of the heating degree-days at this location. In Figure 2, the heating degree-days for Metsovo and 3 other towns—calculated by the available meteorological data—are presented.

Energy needs

In Table 1 the data for energy consumption in Metsovo and its environmental and financial impacts are summarized. Fuel prices used were: 1.13 US$/L for diesel, 142 US$/tonne for firewood, and 0.17 US$/kWh for electrical energy. The diesel and firewood prices refer to the average prices of those fuels in Greece between October 2010 and April 2011. The heating source referred to as "other" is assumed to be a combination of diesel oil heaters, open fireplaces, and electrical heaters, following the results of the field survey. In order to calculate the particulate matter emissions for the heating systems currently used, several estimates were combined (Johansson et al 2004; Greenpeace 2007; EEA 2009; NAEI 2009). The CO_2 emissions were obtained by the Greek Public Power Corporation.

According to Table 1, and bearing in mind that the number of households in Metsovo is 750, the average annual thermal energy consumption per household was 23,408 kWh, of which 93% is needed for space heating and 7% for water heating. The cost of this amount of thermal energy is US$ 2293 per year. The thermal energy costs corresponded to 7.1% of the average annual income of the households, which was US$ 32,135.

Electrical energy consumption—excluding electrical energy consumption for heating purposes—was estimated at 6833 kWh/household, on an annual basis, following the results of the field survey. This corresponds to US$ 1161

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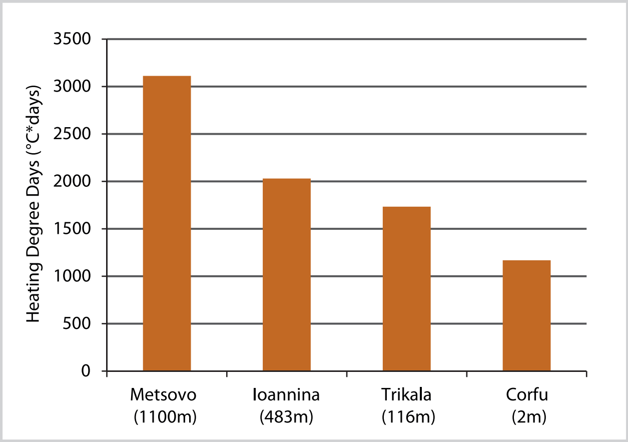
FIGURE 2 Heating degree-days of 4 Greek towns.



per year. Electricity consumption in Metsovo is significantly lower than the corresponding average consumption in Greece.

Energy efficiency of buildings

The available statistical data show that 89% of the total thermal energy demand of the households in Metsovo comes from buildings constructed before 1985. The majority of these houses are stone-built, and their insulation standards are very poor.

After taking thermal images of the residencies in Metsovo and analyzing the statistical data, some useful conclusions were reached (Figure 3):

- Houses built before 1970 and between 1971 and 1985 had particularly low energy performance. About 75% of them were not insulated, and almost all of them had obsolescent window frames. These houses need to be insulated, and their window frames should be replaced.
- Houses built between 1986 and 1995 had better energy efficiency, mainly due to the fact that their walls were insulated. Their thermal losses were mainly attributed to window frames that should be replaced.
- The thermal energy demand of houses built after 1996 represents only 2% of the total demand. Their energy performance was generally good. So no action for those buildings is proposed.

Metsovo and energy poverty

Overall, 10.7% of the households' annual income was required for energy expenses, taking into account both heating and the electrical energy costs. This percentage was slightly higher than the "energy poverty limit," which means that Metsovo is vulnerable to energy poverty. After a more thorough look at the distribution of household income, it was apparent that a significant number of people already faced great difficulties in covering their energy needs. More specifically, 114 households had annual incomes of less than US$ 14,125. For these people energy expenses represented more than 24% of their income, meaning that they are obviously not capable of covering their energy needs sufficiently.

The Greek government has announced that fuel taxes will be dramatically increased in October 2011. Diesel oil

TABLE 1 Thermal energy consumption and its environmental and financial impacts in Metsovo.

Thermal energy system	Energy consumption (kWh)	Annual CO_2 emissions (tons)	Annual PM[a] emissions (kg)	Annual cost (US$)	Ratio of heating costs to households' income (%)
Space heating	**16,323,113**	**3509**	**3599**	**1,591,010**	**6.6**
Diesel oil–fired heaters	11,679,969	2995	196	1,314,890	
Wood-fired heaters	1,137,660	0	102	42,045	
Wood stoves	1,034,236	0	931	38,081	
Other	2,471,248	514	2370	195,994	
Water heating	**1,232,755**	**395**	**39**	**129,014**	**0.5**
Boiler heated by diesel oil	741,554	190	13	83,482	
Boiler heated by wood	285,214	0	26	10,540	
Electrical boiler	205,987	205	0	34,992	
Total	**17,555,868**	**3904**	**3638**	**1,720,024**	**7.1**

[a]PM: Particles with a median diameter of less than 10 μm. The amount present in the atmosphere is used as an indicator of the level of pollution.

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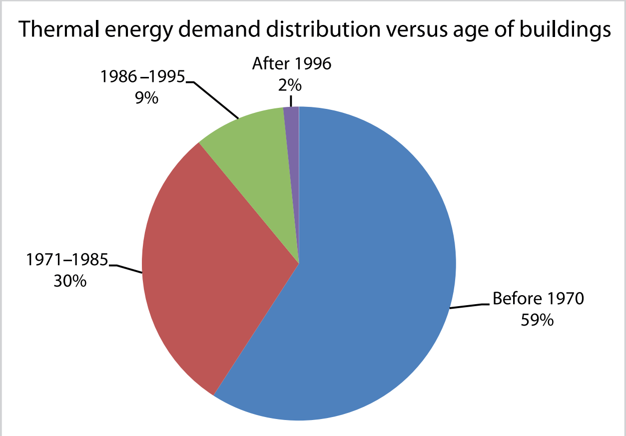
FIGURE 3 Distribution of thermal energy demand in Metsovo versus buildings' age (according to the Greek Energy Information System).



will rise from US$ 1.13/L to about US$ 1.69/L, an increase of 50%. This means that the average portion of household income needed for energy expenses will rise to 12.2% in Metsovo, not to mention that Greek gross domestic product is expected to decrease in 2012. Therefore, the problem of energy poverty will be further intensified (especially for low-income households) under the effects of the current economic crisis, so there is a definite need to take action.

Possibilities of exploiting renewable energy potential and applying energy-saving measures

Metsovo is surrounded by large forests. Between 1988 and 2008, the average firewood production was 5000 tonne/y, according to the local forestry authorities. This quantity is sufficient to cover the thermal energy needs of about half of the households. So far, only 13% of the households cover their energy needs with wood-fired systems. Therefore, there is an important local biomass potential that can be utilized. It should be noted that the forests are publicly owned and are exploited on a cooperative basis.

The annual portion of solar irradiation in the area of Metsovo is 1660 kWh/m^2 on a horizontal plane (PVGIS, 2008). This important solar energy potential is practically unutilized in Metsovo. Solar systems are not used in the town, because of legal restrictions that aim to protecting the vernacular architecture of the town. So incorporating renewable technologies in traditional buildings—with consequent revision of current legislation—is a prerequisite for taking advantage of solar energy.

As far as energy saving is concerned, interventions in the buildings' shell are necessary to lower thermal loads. According to the Technical Chamber of Greece (2010), improving the shell of a building can have the following results:

- Thermal insulation of walls: 20–25% energy savings;
- Replacement of window frames: 25–30% energy savings.

Alternative scenarios for lowering energy consumption

In order to devise a strategy for more rational energy use that will help to confront energy poverty, it is necessary to create alternative scenarios of varying economic and technological intensity. In accordance with the special characteristics of Metsovo, 5 alternatives have been created (see Box 1).

BOX 1: Alternative scenarios for reducing conventional fuel use in Metsovo

Alternative 1: Installation of solar collectors for hot water heating. This option includes the installation of solar systems in 575 households using diesel oil–fired and electrical boilers.
Alternative 2: Installation of domestic biomass–fired heaters. This scenario includes the replacement of diesel oil–fired heaters with biomass heaters. Locally produced biomass can cover the needs of 375 households.
Alternative 3: Thermal insulation of walls and replacement of window frames. This option promotes energy-saving interventions in the building shell. Thermal insulation would be added to residences built before 1985, and replacement of window frames would be applied to houses built prior to 1995.
Alternative 4: Building shell improvement and use of domestic biomass–fired heaters. This is a combination of alternatives 2 and 3.
Alternative 5: Building shell improvement, use of domestic biomass–fired heaters and installation of solar collectors. This is the most complex scenario that combines alternatives 1 and 4.

The investment costs for each alternative, the economic benefits, the external benefits (monetary value of the environmental benefits), and the contribution to reducing conventional fuel use are given in Table 2. Calculation of external benefits was based on Butti et al (2008) and the results of the ExternE research project. The investment costs were estimated after a thorough search of the energy products market in Greece and by taking into account the model house in each age category. Taking the age category "before 1970" as an example, the model house has the following characteristics:

- Area: 72.36 m^2; volume: 217.08 m^3; area of openings: 23.75 m^2; number of floors: 1;
- Shell construction materials: stone; construction materials for openings: wood; insulation: none.

TABLE 2 Financial costs and benefits, external benefits, and reduction in conventional fuel use for each alternative.

Alternatives	Investment cost (US$)	Annual economic benefit (US$)	Annual external benefit (US$)	Reduction in conventional fuel use (%)
1	581,125	94,778	47,473	5.5
2	1,486,433	327,228	489,807	59.5
3	4,903,672	761,110	468,468	44.5
4	6,351,883	951,813	723,905	77.7
5	6,566,708	990,941	733,753	79.6

Assessment of the alternatives

A feasibility study was conducted for financial evaluation of the alternatives. The lifetime of the investments was taken to be 15 years, and the discount rate was considered to be 5% (Christodoulou 2010). The criteria of the Net Present Value (NPV), the Internal Rate of Return (IRR), and the Payback Period (PP) have been used. The feasibility study was supplemented with estimates of the contribution of the alternatives toward combating energy poverty. The ratio of the annual energy expenses to the average household's income is calculated following each energy intervention (Table 3).

All the investments had positive NPV, IRR higher than the discount rate, and PP less than 15 years, which is considered to be their lifetime. The increased thermal energy needs of mountain settlements in combination with high diesel oil prices were the main reasons for the good financial performance of the energy-saving interventions.

The replacement of diesel oil–fired heaters with biomass heaters had remarkably good financial performance and seemed to be the most efficient intervention for reducing fuel costs in Metsovo. Apart from the direct economic and environmental benefits, forest biomass exploitation has broader positive results in mountainous areas. More specifically, the existence of forest production can contribute to forest revitalization and creation of workplaces.

The assumptions about the lifetime of the investments and the discount rate were in accordance with the corresponding assumptions commonly made for energy-saving projects in Greece. However, a sensitivity analysis was carried out in order to assess the influence of the discount rate on the performance of the alternatives. As depicted in Table 4, a variation of ±20% in the discount rate did not seem to have a very significant influence on the investments' performance. All of the alternatives remain viable, and 3 of them present a 1 year's increase in the PP if the discount rate grows by 20%.

The prices of the fuels proved to be more important for the viability of the investments. In particular, the price of diesel oil had a more intense influence on the performance of the alternatives. For example, in the case of applying thermal insulation to the shell and replacing the window frames, if the diesel oil price decreases 15%, then the PP increases from 9 to 13 years, and the NPV shrinks to 33% of the initial value. Figure 4 shows the impacts of the variation of the diesel oil price, the firewood price, and the discount rate on the PP of the second alternative (use of domestic biomass heaters).

Nevertheless, the contribution of the alternatives to combating energy poverty cannot be based solely on economic performance. The use of biomass heaters reduces the percentage of energy expenses to 9.4% of annual income. Combining biomass heaters with energy-saving interventions brings about further reduction, and the ratio percentage drops to 6.8%. Adding solar systems

TABLE 3 Economic performance of the alternatives and ratio of thermal energy expenses to the households' income.[a)]

Alternatives	NPV (US$)	IRR (%)	Payback period (y)	Thermal energy expenses to household income ratio (%)
1	310,908	12	9	6.7
2	1,910,004	21	6	5.8
3	2,214,666	11	10	4.0
4	2,639,656	11	10	3.2
5	2,830,973	11	10	3.0

[a)]NPV: net present value; IRR: internal rate of return.

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TABLE 4 Variation in the payback period of the alternatives with respect to changes in the rate of return.

Alternatives	Payback period (y)				
	Rate of return				
	4%	4.5%	5%	5.5%	6%
1	8	8	**9**	9	9
2	6	6	**6**	6	6
3	10	10	**10**	10	11
4	10	10	**10**	11	11
5	10	10	**10**	10	11

for hot water production reduces the percentage to the minimum possible value of 6.6%. It should be noted that the fifth alternative was of significant help for the financially weakest part of the town of Metsovo. People obliged to spend 24% of their income for energy would be greatly relieved after applying this alternative, since they would need to spend about 15% of their income. However, this amount is still higher than the energy poverty limit, and under current conditions, people with low incomes need support to cover their energy needs sufficiently.

As far as environmental performance is concerned, it is obvious that the most complex alternative has the most positive environmental impact. The fifth alternative results in very low dependence on conventional fuel, at the level of 20%. The alternative with the best economic performance also showed good environmental performance, resulting in about a 60% reduction in conventional fuel use and CO_2 emissions. Widening the use of biomass may also have negative environmental consequences related to the increase in particulate matter emissions, even if the new biomass heaters follow strict standards such as the EN 303-5. However, due to meteorological conditions in Metsovo, which include N and NW winds with velocities over 5 m/sec on a regular basis, this slight increase in particulate matter emissions is not expected to affect the environmental quality of the air.

Conclusions

It is clear that increased fuel use in mountainous areas make them particularly vulnerable to energy poverty, owing to the harsh weather conditions. As illustrated in the case of Metsovo, by applying the proposed methodology, pathways leading to combating energy poverty can be found. Mountainous areas should overcome the risk of becoming "energy poor," as many of them are situated in locations that are "energy rich."

In Metsovo, expanding the use of domestic, biomass-fired heaters resulted in high financial performance and helped to reduce conventional fuel use. This constitutes a solution with reasonable investment costs and direct positive effects on reducing energy expenses. A more integrated solution, with greater effects on energy poverty, would be a combination of biomass use with energy-saving interventions. This strategy can have more positive consequences on a long-term basis. However, the required investment costs are particularly high (Figure 5).

It seems that a policy providing financial incentives to apply energy improvement interventions is necessary to improve the Metsovo energy profile. The Greek government has designed a program, called "save at home," that promotes energy saving by providing subsidies to specific categories of households. More specifically, the houses eligible for energy improvement are those built before 1989 in areas with relatively low land prices. State support is of significant help to households with annual incomes less than US$ 42,577 and includes a 35% subsidy and a 65% interest-free loan.

A disadvantage of the "save at home" program is the fact that it does not include a criterion related to the intensity of energy demand. It is reasonable that areas with increased energy demand should have priority where energy improvement is concerned, but this is not part of the current energy-saving policy. Therefore, Greek mountainous settlements are not receiving significant assistance in changing their energy profile. Since

FIGURE 4 Sensitivity analysis related to alternative 2 (use of domestic biomass heaters).

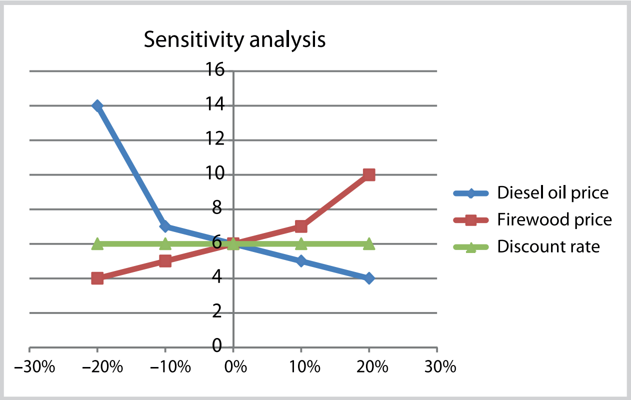
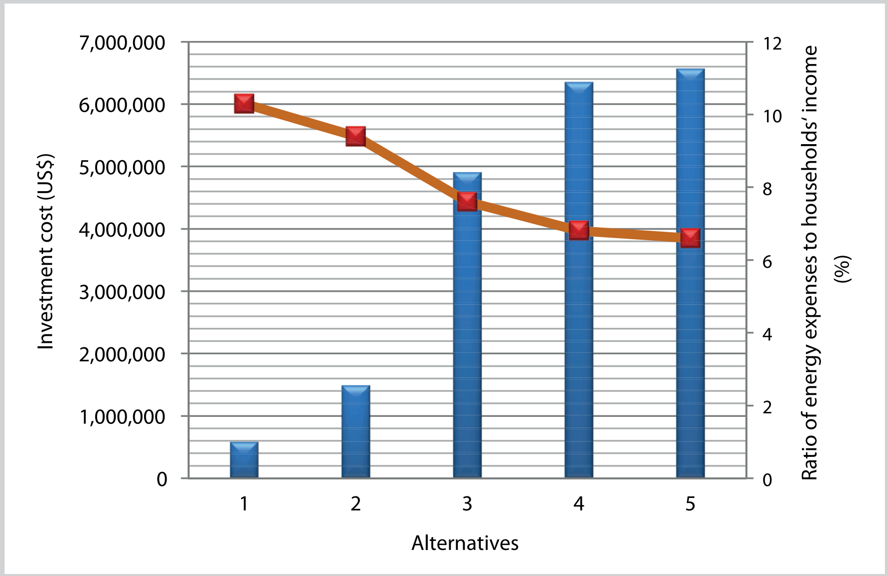


FIGURE 5 Investment costs and contribution of each of the 5 alternatives toward mitigating energy poverty.



mountainous areas are more vulnerable to energy poverty, it is clear that a special energy policy framework should be created for them.

The economic and environmental benefits of applying sustainable energy measures in mountainous areas are not only of local importance. It should be noted that reduction of conventional fuel use could reach almost 80% in Metsovo. This has far more positive effects than the "20–20–20" objective.

The economic effects are not only important for local society, but also for the Greek economy in general. Diesel oil demand in Greece—and in the majority of European countries—is basically covered by imports, with consequent macroeconomic impacts. Therefore, every action that reduces dependence on diesel oil has a generally positive result in economic terms.

In conclusion, taking into account the analysis done for Metsovo, several key factors of interest to mountain areas in general can be highlighted:

- Energy poverty is a serious social issue and combating it should become one of the main priorities of mountain policy, since mountain settlements are particularly vulnerable to it.
- Utilization of locally available biomass is a key to lowering fossil fuel consumption for heating purposes in mountainous areas, provided that the production of firewood follows the principles of sustainable forestry. However, the whole procedure of biomass production, even under the principles of sustainability, can have multiple impacts on the forest ecosystem. Hence, further research is needed in this field in order to minimize the side effects of biomass use.
- Special financial incentives should be given to mountain populations to apply energy-saving measures. The economic and environmental effects of such a policy can be highly positive, at the local level and beyond.
- Mountain communities such as Metsovo could be assisted in implementing a sustainable energy policy through knowledge exchange with communities that have applied successful energy strategies, like Trento in Italy. Creating communication networks between mountainous areas is a prerequisite for effective knowledge transfer. EU-funded programs, such as COST, can be utilized to this end.

The case of Metsovo shows that the economic crisis should not be an excuse for inaction. On the contrary, mountain communities can overcome the impacts of the problem of covering energy needs by promoting 2 of the basic elements of the energy strategy proposed by EUROMONTANA for mountain areas:

- Energy efficiency to the greatest extent possible;
- Energy production at local level from diverse resources.

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