Sustainable and efficient energy supply for the development of tourist villages at the Adriatic and Ionian Sea

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Abstract

The increasing number of tourists in small villages at the Adriatic and Ionian Sea causes problems in view of marine pollution, energy consumption, CO_2 emissions and the accumulation of waste. Aim of the project is the development of an overall sustainable EcoTourism. To reduce energy consumption, the refurbishment of buildings and implementation of renewable energy will be in focus.
Various measures, from thermal renovation to changing the heat and cooling generators, are considered and analyzed. Energy consumption can be reduced up to 10 – 70 % by refurbishment (wall, window, roof). Changing generators can achieve a reduction in energy demand of around 30 %. However, the investment costs or the resulting total annual costs of thermal improvement do not reflect the energy saving results. Here, the measures regarding replacement and renewal of the heat and cooling generators are more economical.

Due to restrictions such as monument protection, not many regenerative concepts can be pursued. However, potential for regenerative generation of heat and electricity is theoretically available. Above all, the use of solar collectors leads to an effective reduction in energy requirements for hot water production, which in any case accounts for the largest share of electricity requirements.

Keywords: renewable energy, energy supply concepts, building refurbishment

1. Introduction

The increasing numbers of tourists in the holiday regions on the Adriatic coast and the Ionian Sea lead to immense seawater pollution, high energy consumption and associated high CO_2 emissions as well as a large amount of waste. Due to the supply and disposal structure that needs improvement, short- and long-term tourists in this region have aggravated the situation in recent years. The landscape and tourism are shaped by the small villages and their hotels, but rehabilitation and necessary measures for environmentally sound and efficient management of the facilities and accommodation have not yet taken place.

The research project "EcoTourism - Regional Development of Tourist Villages of the Adriatic Sea through Energy Efficient and Sustainable Supply and Waste Management" focuses on smaller villages and their hotels and "Bed & Breakfast" facilities, whose supply and waste management are at a comparatively environmentally harmful and inefficient level.
Within the framework of the project, transferable, country-specific concepts in the areas of energy, wastewater and waste for sustainable supply and disposal will be developed as a basis for ecologically sustainable tourism, which will serve as best practice examples and be easily transferable to all villages in the countries under consideration.

> Goal - Energy: Transformation into climate-friendly and energy-efficient tourism. Holistic approach to the economic and ecological optimization of energy supply and reduction of energy consumption (heating, cooling and electricity) of existing buildings as well as use of renewable energy sources.
>
> Goal - waste water: Wastewater solutions and concepts for the greatest possible recycling, taking into account quality standards and energy efficiency. The focus is on sustainable tourism use.
>
> Goal - waste: Reduction of the amount of waste as a causal source of environmental pollution and introduction of an energetic bio-waste utilization for energy generation as well as a material utilization of recyclable packaging.

The concepts and simulations presented below are based on a pilot village in Albania but can be transferred to other

doi:10.18086/eurosun.2022.02.01 Available at http://proceedings.ises.org

"ideal villages of the Adriatic" in a further step.

So far, holistic, sustainable, and transferable energy concepts for the implementation of climate-friendly and energy-efficient tourism have been developed. Furthermore, the potentials for the use of renewable energies in the neighborhood were determined and the possibility of integration was evaluated in order to present a transferable, implementable, sustainable and energy-efficient supply concept.
The wastewater solutions and concepts will be developed specifically in the direction of the greatest possible recycling (water and nutrients), consideration of quality standards (pollutants and hygiene) and energy efficiency (including the energetic use of wastewater resources), considering the relevant national and international standards on wastewater treatment and water reuse.
With regard to waste management, the current status is examined and placed in the context of current concepts and technologies. Based on this, a sustainable waste management concept will be developed.

2. The pilot project

Dhërmi is a village in the south of Albania in the municipality of Himara. In the region of Sarande and Himare, several villages and areas have been declared UNESCO World Heritage Sites. Thus, the historical core of Dhërmi is also under historical/cultural monument protection. The historical centre of Dhërmi is situated high above the coast of the Ionian Sea and is built into a rock face. Induced by seaside tourism, a second village district developed near the coast. In recent years, the tourist infrastructure of Dhërmi has been steadily expanded and the number of holidaymakers, especially from other parts of Albania, is increasing. Primarily, however, these are bathing tourists. This new core is not subject to monument protection, as it differs greatly from the historical core of Dhërmi in terms of building structure and construction. The subject of the pilot project is the historic old core of the village of Dhërmi.

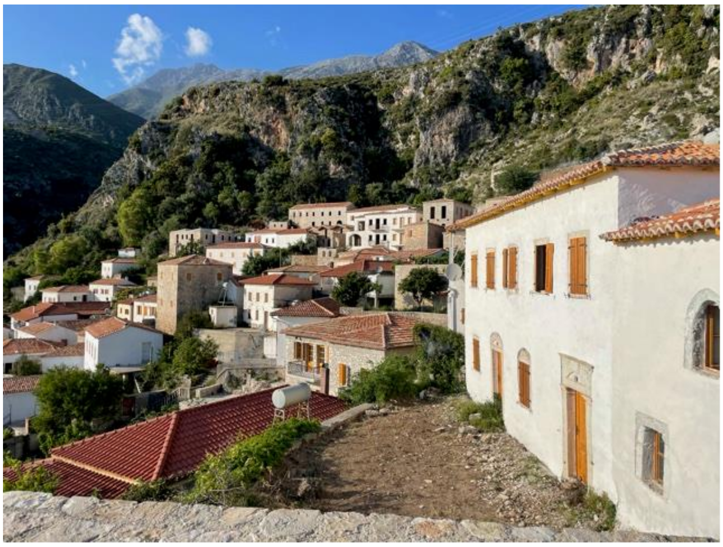

Fig. 1: View Mountain village of Dhërmi

In the project area under investigation (116 buildings in the centre of Dhermi), three different construction types can be identified for the buildings. Old building, mixed building and new building. It can be assumed that these building types will also be present in other areas under consideration. (Table 1)

The old buildings are characterized by plastered but also unrendered facade made of natural stone, small windows, hipped roofs with a wooden beam construction and clay tiles. The old buildings usually do not have balconies. New buildings, which are based on the architectural style of the historical old buildings, do not differ significantly from the old buildings in terms of the building substance and the building materials as well as the cubature and are treated as such in the further processing. Purely new buildings, on the other hand, have a facade of reinforced concrete skeleton construction with brick infills. In general, these houses have larger windows than the old buildings, balconies primarily on the south and west facades, and flat concrete roofs. The third building style is a combination of old and new construction, or mixed construction. These are either new buildings, which have a reinforced concrete skeleton construction, but have a hipped roof with clay tiles, or mixed buildings as new additions to old buildings. (Figure 2)

Fig. 2: Examples of building stock: old (left), new (middle) and mixed (right) building

Tab. 1: Assumptions of the component structures of the different building types

	New building	**Mixed building**	**Old building**
Outside wall (to air)	1 cm gypsum plaster 25 cm vertically perforated brick 2 cm exterior plaster	1 cm gypsum plaster 25 cm vertically perforated brick 2 cm exterior plaster	1 cm gypsum plaster 45 cm natural stone 4 - 5 cm plaster and lime mortar
Outside wall (to ground)	1 cm gypsum plaster 25 cm reinforced concrete	1 cm gypsum plaster 25 cm reinforced concrete	1 cm gypsum plaster 45 cm natural stone
Ground floor	0.5 cm tiles 25 cm normal concrete 30 cm sand and gravel layer	0.5 cm tiles 25 cm normal concrete 30 cm sand and gravel layer	0.5 cm tiles 25 cm normal concrete 30 cm sand and gravel layer
Ceiling	1 cm gypsum plaster 25 cm reinforced concrete 0.5 cm screed	1 cm gypsum plaster 25 cm reinforced concrete 0.5 cm screed	2.5 cm wooden battens (Beech/ Oak) 15 cm clay 2.5 cm wooden battens (Beech/ Oak) Floorboards
Roof	25 cm reinforced concrete	2.5 cm wooden battens (Beech/ Oak) Air layer 3 - 5cm ceramic/ clay tile	2.5 cm wooden battens (Beech/ Oak) Air layer 3 - 5cm ceramic/ clay tile

3. Energy supply concepts and refurbishment

The processing and analysis of possible energy supply concepts base on the facts that

- no or only little renewable energy has been implemented so far.
- there is a high demand for heating and cooling. With respect to thermal insulation buildings have a poor standard and until now have not been refurbished.
- heating and cooling are provided room by room by wood stoves and inefficient split units, respectively.
- listed (heritage) buildings complicate a thermal refurbishment and the implementation of renewable energy in several cases.

Since it has not been possible to carry out a comprehensive review of the current situation of the buildings, the heating and cooling requirements for the three references (old, mixed and new building) has been determined by means of thermal simulation using TRNSYS. The heating and cooling demand is calculated on the basis of an example building with the help of the thermal simulation. The example building is created as a simplified building model for the defined three building styles with a gross floor area of 240 m² and is divided into five residential units (average 48 m²) with an occupancy of 2.6 persons per unit. Furthermore, a distinction was made between summer season with full occupancy and low season and winter season with half season. Care was taken to ensure that the building models of the old, new and mixed buildings corresponded to the description of the respective building types and that the defined component structures were applied.

As a result of the simulations, specific heating and cooling energy requirements are obtained for the three building types. With around 68 kWh/(m²a) and around 17 kWh/(m²a) in relation to the gross floor area, the old building has the lowest heating and cooling energy requirements. With around 103 kWh/(m²a) for heating and 18 kWh/(m²a) for cooling, the mixed building is in the middle. The new building has the highest heating and cooling energy requirements with around 104 kWh/(m²a) and 29 kWh/(m²a). (Figure 2)

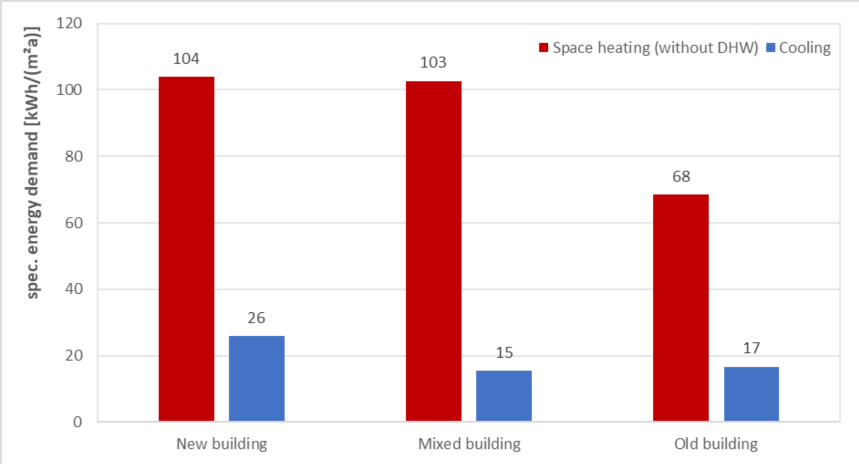

Fig. 2: Specific energy demand of heating and cooling for the three building types

The results are extrapolated to the three building categories and to the entire neighborhood using the data from the survey of the buildings. The energy requirements for the total reference area of 116 buildings (without refurbishment) results to 2,470 MWh/a for space heating and 822 MWh/a for space cooling as well as 2,143 MWh/a for domestic hot water production. (Figure 3)

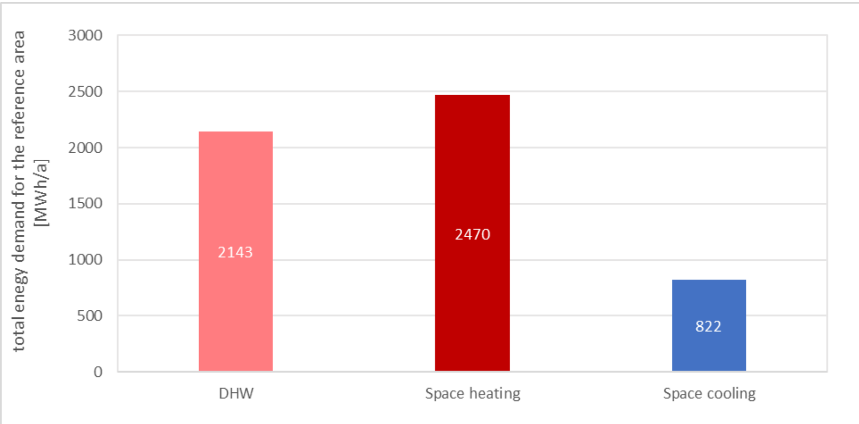

Fig. 3: Heating and cooling demand of the reference area

3.1 Thermal refurbishment

In order to save additional energy in addition to a new efficient heating and cooling supply, thermal refurbishment measures are recommended, which can also be implemented within the framework of an existing listed building. For thermal refurbishment, minor construction measures within the houses and flats are considered. Nevertheless, at the time of refurbishment, the houses can usually not be rented out.

The proposed refurbishment stages differ in terms of the effort required or the building components to be insulated and the insulation thicknesses (Table 2). All renovation stages can be applied equally to all three building. Since the building types differ in their previous construction, the savings potential of the renovation levels depends on the building type. Within each renovation level, differences are made in the renovation of the windows, the walls and the roof.

To reduce the energy consumption of the buildings, six refurbishment levels have been defined. Taking the protection of historical monuments into account, the levels range from low (level 2) to a high effort for refurbishment (level 6).

Tab. 2: Examples of refurbishment levels

Level	Refurbishment measures	Comment
1	Replacement of the windows: 2 panes, sun protection glazing	
2	Level 1 + thermal insulation of the roof (10 cm)	Minimal invasive version
3	Level 1 + thermal insulation of the wall and roof (5 cm)	
4	Level 1 + thermal insulation of the wall and roof (10 cm)	
5	Level 4 + thermal insulation of the base plate (3 cm)	
6	Level 1 + thermal insulation of walls (10 cm) + roof (12 cm) + base plate (5 cm)	Highest effort

3.2 Energy supply refurbishment

The energy supply concepts are analyzed and evaluated on two levels. On the so-called room level, the individual usage zones or rooms within the building are considered. Here, the focus is on the respective heat or cold transfer system in the room. Furthermore, the type of ventilation (window ventilation, mechanical ventilation) plays a decisive role and to what extent the existing systems can influence each other.

The building level, on the other hand, reflects the overall concept (total system) with the corresponding building envelope as the system boundary. Within the framework of the overall system, the generation and distribution of heat and cooling are considered. It should be possible to implement efficient and regenerative producers as well as a possible division of the base and peak load suppliers. The division of base and peak load only makes sense for larger houses.

The supply concepts presented are primarily standard solutions rather than individual solutions, so that the concepts developed can also be applied to a large number of houses. A large variance in the concepts at room and building level can lead to confusing regulations and dependencies of the individual components. The standard solution here is a simple combination of a maximum of two components.

The focus is on the implementation of regenerative-based energy supply concepts and systems for holiday homes / flats under a holistic consideration of heating / cooling and electricity. The consideration also includes the sustainability of the components as well as possible obstacles in the implementation of the different approaches. The six variants developed are based on technologies currently relevant to the market (Table 3).

In addition to decentralized energy supply solutions such as air-conditioning split units, heat pumps and gas boilers, local heating network approaches are also included. The generators must be able to meet the energy demand for both heating and cooling, or a combination of both. The combination of different generators for base and peak load coverage is one possibility. However, for residential buildings and on the scale at hand, it cannot be implemented efficiently and does not make sense. A division into heating and domestic hot water should be considered in order to cover the different temperature levels efficiently.

Table 2 lists the supply concepts being applied. As due to monument protection, photovoltaics and solar thermal collectors may not be installed on individual houses and are not listed, therefore.

In the course of finding the energy supply concept and selecting the possible components for heat/cold and electricity generation as well as heat and cold distribution in the building, approaches were already discarded or excluded in advance.
Components and concepts that require a major refurbishment effort in the existing building stock and cannot be implemented easily include floor heating, concrete core activation, air handling units and for the heat pumps borehole heat exchanger. However, these components could be used in a complete refurbishment and gutting of houses.

Tab. 3: Options for energy supply concepts

	Option	Heat supply	Cold supply	Domestic hot water
Decentral energy supply	As build	Existing split units	Existing split units	Instantaneous water heater
	1	New split units	New split units	Instantaneous water heater
	2	Gas boiler and buffer storage	Compression chiller	Gas boiler and buffer storage
	3	Heat pump and buffer storage	Rev. heat pump and buffer storage	Heat pump and buffer storage
	4	Electrical heater	Compression chiller	Instantaneous water heater
Central energy supply	5	Local heating network (60°C)	Local cooling network (15°C)	Local heating network (60°C)
	6	Local heating network (0°C), heat pump and buffer storage	Local cooling network (15°C)	Local heating network (60°C), heat pump and buffer storage

4. Potentials on energy reduction

In the context of the presentation of the potentials of energy savings through thermal refurbishment as well as through the change of the heat / cooling generator, it is taken into account that there will be an increase in the number of tourists in the holiday resorts. The user behavior and the higher tourist numbers are compiled in the studies within the framework of the heating and cooling profile of the building simulation, the domestic hot water profile, and the electricity demand profile.

4.1 Energy reduction through thermal refurbishment

Based on the defined example buildings and the location in Albania, the heating and cooling demand is determined, and the renovation stages are compared with the demand of the actual state (figure 4). It can already be noted in the actual state that the old building has lower energy requirements (heating and cooling) than the mixed and new buildings. Refurbishment level 2 can already achieve a reduction in energy demand of up to 15%. In total, a reduction in energy demand of up to 70% can be achieved by refurbishing all building components (refurbishment level 6). The renovation of new and mixed buildings has the greatest savings potential, as the buildings already have a higher demand in their current state than the old building.

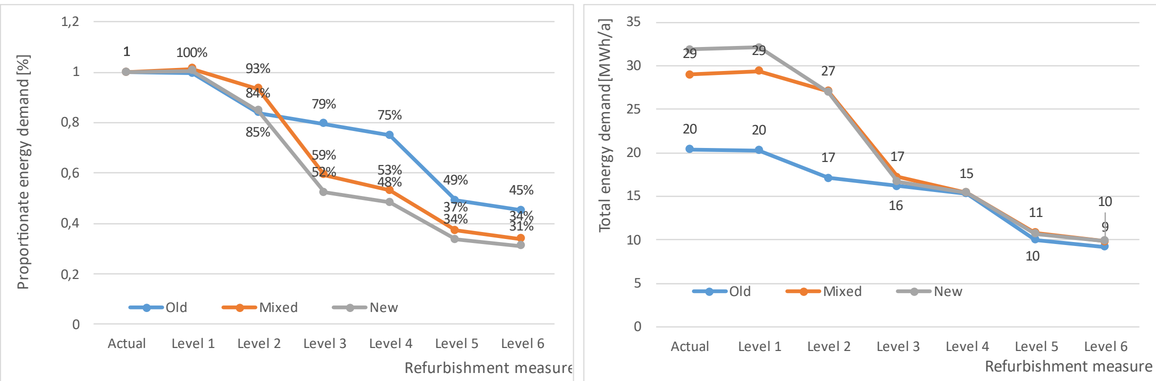

Fig. 4: Energy demand reduction and potentials for the entire reference area and for the different refurbishment stages

4.2 Energy reduction through system technology

Figure 5 shows the first results for different variants of energy supply concepts developed for the project area (116 houses). Based on the results it can be stated that the way of heat and cold generation has much greater influence on the reduction in energy consumption than the refurbishment of the buildings. The energy demand calculated for the reference area includes electricity for households and domestic hot water preparation.

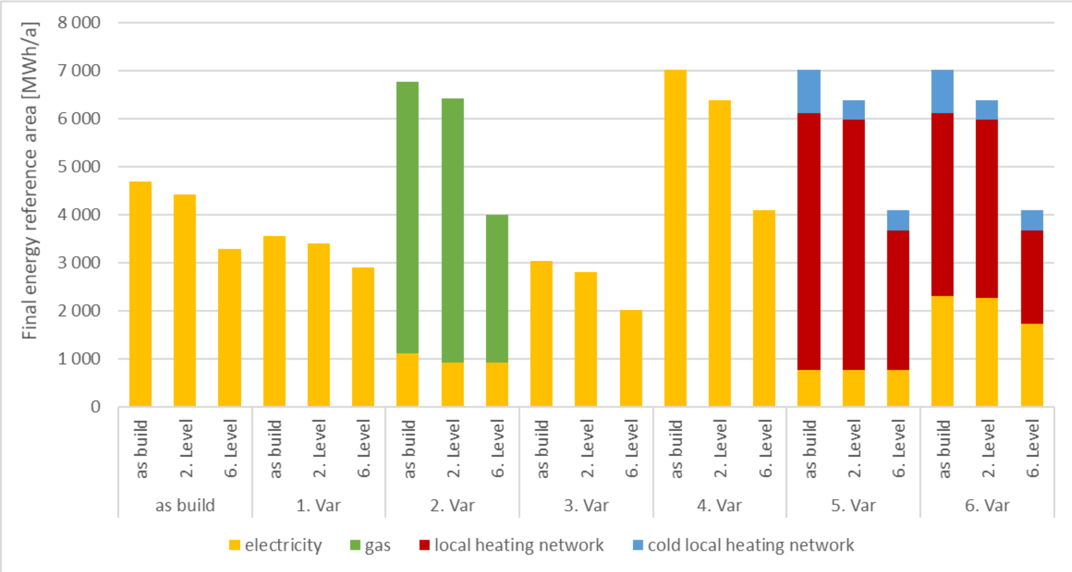

Fig. 5: Energy demand of the reference area depending on the refurbishment level and the energy supply

The fact that the individual heat and cooling generator technologies have different modes of operation also results in different efficiencies. Air-conditioning split units, for example, use a proportion of outdoor air heat or cold to condition the rooms. This means that a lower proportion of electricity or final energy is required here. A gas condensing boiler, for example, does not convert all the thermal energy in the fuel into heat. Due to losses, an efficiency of only 95% can be achieved here. This situation results in different energy requirements for the different variants.

Exclusion criteria for the selection of variants to be implemented result from the outstanding ecological and economic considerations as well as the feasibility of implementation in the reference area. In this project, for example, due to protection of historical monuments and the preservation of the ancient village appearance, the utilization of renewable energy close to buildings is only possible to a very limited extent - although the location is predestined for the installation of photovoltaics and wind power plants. By relocating a small wind farm outside the village and implementing photovoltaics on the flat roofs of new buildings and a public car park, it is nevertheless assumed that 80% of the electricity demand can be covered by renewable energy.

5. Potentials of solar energy use

The current state of implementation and integration of solar thermal and photovoltaic is very limited. In general, there are very few solar thermal systems or solar siphons in the pilot village. In 20 buildings of the 116 considered, solar siphons were visible, which corresponds to 17 % of the considered houses. The installed solar collectors are often installed on the hipped roofs and flat roofs or next to the building in gardens. The collectors are oriented in a south-west direction with an angle of inclination of 10 - 45°. (Figure 6)

Fig. 6: Solar siphons in the garden (left) and on the roof (right)

Photovoltaic systems, on the other hand, are not installed at all. Many of the historical buildings are under monument protection. The installation of solar collectors or photovoltaic systems on the roofs or facades is not permitted due to the preservation of the historic village image.

Within the framework of the research project, it should nevertheless be shown which possible potentials exist for the use of solar energy sources, also in order to transfer the results and concepts to other villages.

5.1 Solar coverage of hot water demand

The personal daily domestic hot water demand is estimated on the basis of typical load profiles and seasonal fluctuations and extrapolated to the entire village area. A domestic hot water heating to 60°C is assumed. The simulation program TRNSYS is used to calculate the possible hourly yields of a flat plate collector. First, all roof surfaces facing east, south and west are assumed as potential collector installation area. Based on the reference building, several scenarios were investigated assuming a southern orientation and an angle of inclination of 30° of the collector: (figure 7)

1. 0.5 m² collector area per person per building: energy reduction for domestic hot water of 48 %.
2. 1.0 m² collector area per person per building: energy reduction for domestic hot water of 72 %.
3. 1.5 m² collector area per person per building: energy reduction for domestic hot water of 80 %.

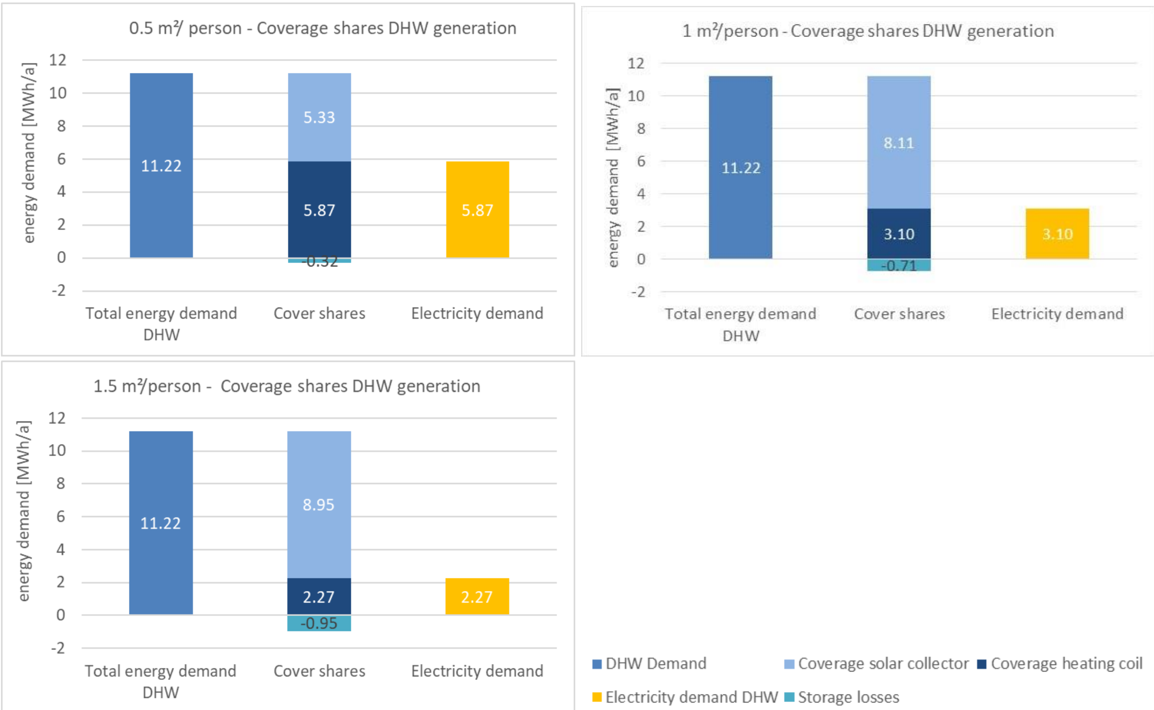

Fig. 7: Coverage shares with solar for the different variants of domestic hot water production for the reference building

For the entire district, an occupancy of 1 m² of collector area per person per building would mean a reduction from 2,143 MWh/a to 600 MWh/a. The additional expenditure for the increase to 1.5 m² per person per building would result in an energy demand reduction of 80 %. However, the additional expense compared to variant 2 does not justify the energy savings here. The recommendation here would be to install 1 m² of collector area per person per building.

5.2 Solar coverage of electricity

A similar study was conducted for the photovoltaic potential. The estimated total electricity demand of the district is 3,770 MWh/a (assumption for Var. 1), which is divided among the different sectors as follows, figure 8. The largest share, 57 %, is accounted for domestic hot water production, with the assumption that this is done electrically.

Two scenarios were examined here. Firstly, the assumption that 75 % of all roof surfaces (also north) and secondly, that 25 % of the roof surfaces (also north) can be covered with PV. An hourly resolved TRNSYS simulation was performed.

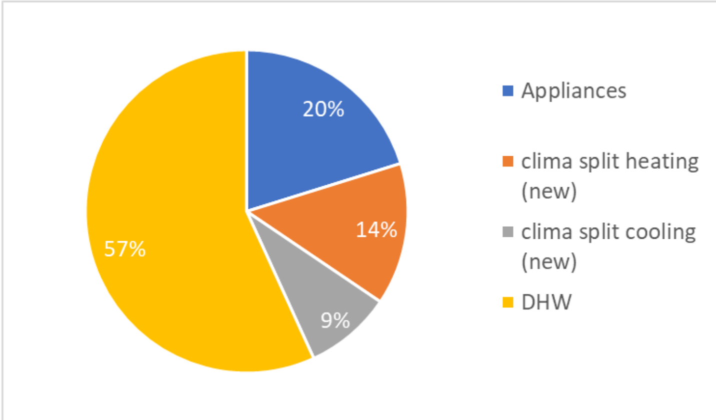

Fig. 8: Shares of electricity demand in the district

In the variant with 75 % occupancy, the energy yield is 1.06 times higher than the energy demand for heating (electric), cooling (electric), domestic hot water, and appliances in the district. Initially, no renovation level was considered in this study. 43 % of the energy demand can be covered by the PV-production itself. 60 % of the yields, on the other hand, are surplus and should have to be fed into the local grid.

In the variant with 25 % occupancy, on the other hand, the yields are 0.29 times lower than the electricity demand of the district. The self-consumption with self-generated electricity is 22 %. However, there is also only 22 % surplus, which can be fed into the grid.

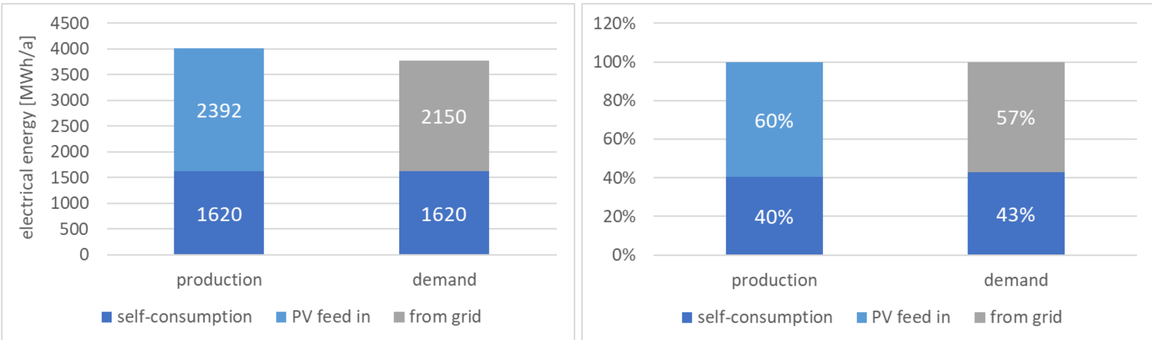

Fig. 9: PV potential for self-consumption, 75 % roof occupancy of the 116 houses

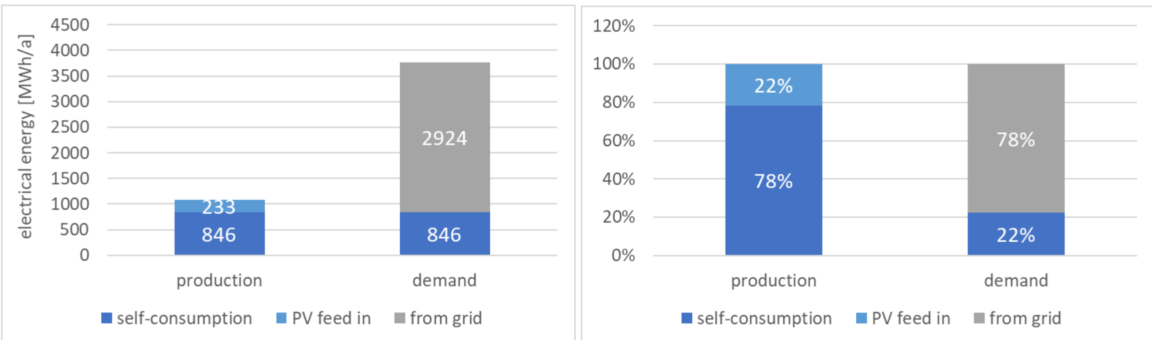

Fig. 10: PV potential for self-consumption, 25 % roof occupancy of the 116 houses

6. Potentials on CO_2 reduction

The potential for CO_2 reduction in Albania cannot be recorded or mapped on the basis of the non-existent CO_2 emissions. In Albania, a CO_2-equivalent of 0 kg/kWh is assumed for biomass (wood), electricity and solar energy. The background is the high production of electricity from hydropower. Only for LPG (Liquefied Petroleum Gas) is a value of 0.227 kg/kWh specified.

7. Economic efficiency

Within the framework of the economic efficiency analysis, the investment costs as well as demand-related and operational costs are taken into account that arise during the purchase and operation of the system components (renovation of the building envelope, heat and cold generators as well as space heating and cooling systems). The economic efficiency is determined using the annuity method (based on the guideline VDI 2067 Part 1 (Economic efficiency of technical building systems) - the total annual costs consist of capital-related, operational (i.e. maintenance and repair costs) and demand-related costs.

The following bases are used in the calculations:

- Costs for planning and contingencies are taken into account at 20 % and 15 % of the investment costs.
- Capital interest rate 5.0 %
- Working price public electricity grid: 0.40 €/kWh (covering 20 % of the demand)
- Energy price for district electricity: 0.24 €/kWh (covers 80 % of demand)
- Energy price increase for electricity is assumed to be 2%.
- CO_2 pricing on electricity not taken into account as well as subsidies

The investment costs are taken from an extensive market research of 03/2022. Since no investment costs from Albania are known and many of the suppliers and installers are supposed to come from Germany, the product and price research is limited to the German market. A cost function was determined depending on the respective performance or dimensioning of the respective component and an average of the entire market was depicted. However, it should be noted that due to the current price increases on the markets, an exact and up-to-date statement is not possible. The economic efficiency analysis merely relates the variants to each other and thus enables a rough economic evaluation.

Figure 11 shows the total annual costs of the variants that could be implemented in Dhermi. It can be seen that variant 4 with electric heating and an additional air-conditioning split unit for cooling the rooms is the most cost-intensive variant, which can lead to additional costs of up to 50 % compared to the current state. By implementing variants 2 and 3, the total annual costs can be reduced by up to 10% compared to the actual state. On the basis of the subdivision into the refurbishment levels, it can be shown that a costly refurbishment of the buildings (Level 6) cannot lead to any cost savings. The heating and cooling generators have the greatest influence on the total annual costs.

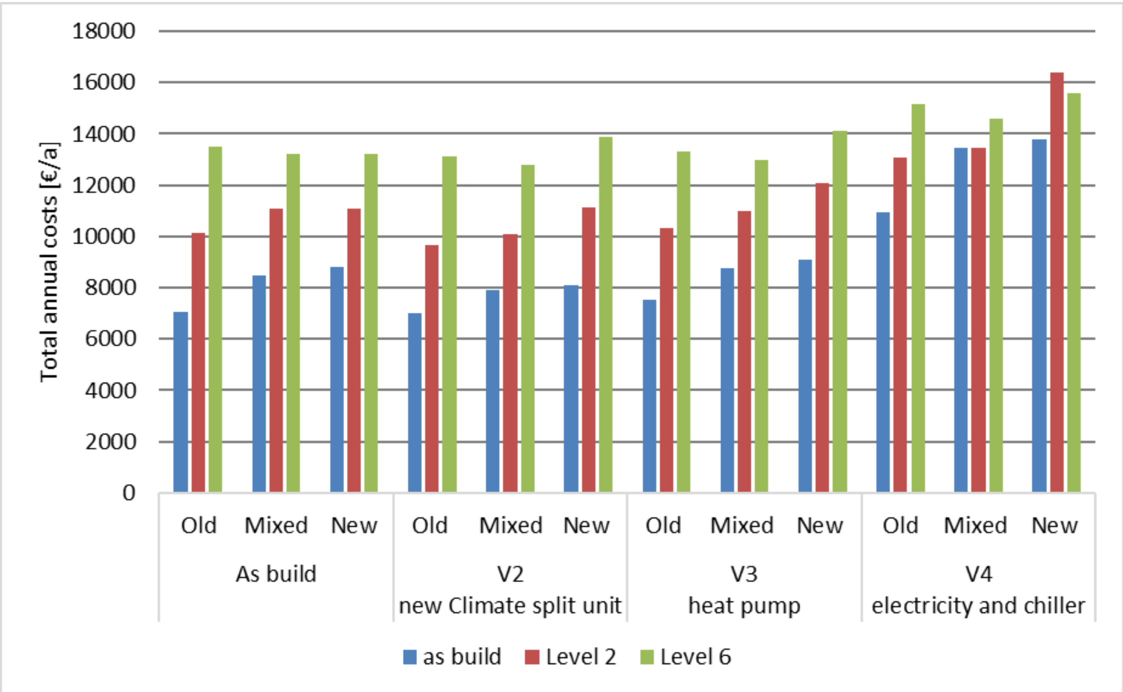

Fig. 11: Total annual costs of possible suppling- and refurbishment-variants of the three building types

8. Summary

The increasing number of tourists in small villages at the Adriatic and Ionian Sea causes problems in view of marine pollution, energy consumption, CO_2 emissions and the accumulation of waste. Aim of the project is the development of an overall sustainable EcoTourism. To reduce energy consumption, the refurbishment of buildings and implementation of renewable energy will be in focus.

The current state of the ongoing project reveals that the development of building standards in foreign countries with different climates is challenging. Demands on the protection of historical monuments require creative solutions, especially in ancient villages. Nevertheless, significant energy saving can be achieved by skillful implementation.

The total energy demand in the reference area of Dhermi is defined as the energy demand for the conditioning of the buildings (heating and cooling) and the appliances. An example building and three building standards were defined and applied to the total number of buildings (116 buildings in the project area). The different periods and occupancies of the buildings are also taken into account. The results show a total heating demand (space heating and domestic hot water) of about 4,610 MWh/a and a demand for cooling of 820 MWh/a for the entire district in Dhermi. In addition to heating and cooling, energy is needed for hot water, for lighting and for all other services in the buildings (cooking, washing, etc.). It is assumed that the entire demand for electricity is covered, the district then needs around 3,700 MWh/a of electricity.

Various measures, from thermal renovation to changing the heat and cooling generators, are considered and analyzed. Energy consumption can be reduced by renovating the building envelope, which can result in a reduction of 10 – 70 %, depending on the building standard and renovation stage. Changing generators to new efficient technology or to a heat pump can achieve a reduction in energy demand of around 30 %. The thermal improvement of the building envelope (windows, roof and walls) is a sensible measure from the point of view of energy saving. However, the investment costs or the resulting total annual costs do not reflect the energy saving results. Here, the measures regarding replacement and renewal of the heat and cooling generators are more economical.

Due to restrictions such as monument protection and the energy sources available at the site, not many regenerative concepts can be pursued. However, potential for regenerative generation of heat and electricity is theoretically available. It can be seen that the utilization of solar energy potentials could lead to a significant reduction in energy requirements in the district. Above all, the use of solar collectors leads to an effective reduction in energy requirements for hot water production, which in any case accounts for the largest share of electricity requirements.
The installation of PV or solar thermal on individual buildings causes difficulties with the appearance and function of the renovated houses (monument protection). A solution for the use of PV is envisaged in the installation of panels on public spaces (e.g. multi-storey car park) and under special conditions (shading) in the project area.

9. Acknowledgments

The research projects "EcoTourism - Regionalentwicklung touristischer Dörfer der Adria durch energieeffiziente und nachhaltige Ver- und Entsorgung" (67EXI4023A_B) were funded by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection by the Export Initiative Environmental Protection GreenTech „Made in Germany". We would like to thank all building owner and operator as well as our project partner Goduni for their help and support as well as providing measurement data and information about the buildings and pilot village.