Environmental impact assessment of Slovenian mountain hut within the scope of sustainable mountain huts in Europe

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Abstract: Remote off-grid mountain huts are specific micro-grid systems which are usually located in sounder environment. As they are not connected to utility grids they require own energy supply for both heat and electricity. While heat is typically provided by fossil fuels and/or biomass, electricity is usually provided by diesel fuelled generators. These types of power generation inevitably cause a lot of environmental impact. The Environmental impact assessment for one Slovenian Pogačnikov Dom hut was made. Specifically CO_2 emissions as global warming potential and NO_x emissions were analysed before and after implementation action. Results shown that with basic investments for installation of additional PV panels and some optimization procedures of the transport with additional education of the staff working in the hut, reductions of 64 % in CO_2 and 54 % NO_x are possible. These results confirm main objective of LIFE SUSTAINHUTS EU project to reduce emissions, producing energy based on renewables and make Mountain huts more sustainable and friendly.

Key words: mountain hut, environmental impact assessment, electricity, heat, renewables

INTRODUCTION

Climate change has been for years one of the most important tasks to be taken into high consideration, both in EU and internationally. In this sense, in order to keep the increase of the global temperature below 2 ºC by 2050, the EU has established the objective of reducing greenhouse gases emissions by 80 % taking as reference GHG levels from 1999, by 2050. The targets for 2020 are also in this line (reducing greenhouse gas emissions by 20 %, increasing the share of renewable energies to 20 % and achieving the 20 % energy efficiency target) [1].

A mountain hut is usually an isolated construction in the mountains, where not only the access to utilities is complicated, but also it is difficult to transport purveyances or fuel supplies. Then, other solutions instead of the usual electricity and gas companies must be considered. Nowadays, the systems providing energy to these facilities are fossil fuel-based, which implies the installation of a diesel generator in order to produce electricity and heat for the heating system and hot water. Moreover, the fuel to be supplied to the generator and other needs to be transported by helicopter in many cases.

Furthermore, Europe depends strongly on imports from foreign countries, which are 80 % of their petroleum reserves. These reserves are usually in unstable regions at political level. Then, this dependence is a clear weakness for Europe´s economy and a major problem to be solved. As it has been stated in the EU document: ‘’the electricity may play the most important role in order to reach the zero emissions by 2050, contributing to replace fossil fuels in transport and heating’’ [2]. In this sense, almost all the electricity and heat that is being consumed nowadays in isolated huts is generated based on diesel consumption. By including the pioneering systems that EU project Life+ Sustain Huts [3] presents, it will be demonstrated how to reduce the dependence of the huts from fuel from foreign countries, promoting renewable generation with almost zero emission as a way of achieving energy independence, sounder environment and making stronger economy.

Additionally, the supply of fuel for transport (helicopters/trucks) and diesel generators involve the extraction and treatment of petroleum to be refined and converted into other products (diesel or kerosene in this case). As a consequence, in case of accident or intentioned release of petroleum, a serious damage for environment appears.

Mountain huts are mainly located in natural parks where pollution is a critical factor and the different authorities look for the best measures to prevent deterioration, contamination and conservation of natural habitats of wild fauna and flora. To maintain that environment the integration of zero emission solutions for providing electricity and heat to the remote located huts it’s necessary in the future.

In order to evaluate the implementation of these effective solutions the Life Cycle Assessment (LCA) should be applied before and after implementation actions [4–7].

As the core of the project Life+ Sustain Huts, innovative climate change adaptation technologies are going to be developed in 9 huts from four different countries (Italy, France, Slovenia and Spain), which will demonstrate that can be easily replicated and transferred to other places independently of the climate, latitude or country. The technologies to be applied will be based on photovoltaic, micro hydro power and wind energy generation, fuel cells, electrolysers, hydrogen storage as well as new insulated materials which will be installed in the huts in order to demonstrate, show and educated in the climate change adaptation.

In present study identification of all technologies used in mountain huts are evaluated in terms of Life Cycle Inventory (LCI) Analysis that will serve as a basis to set up a general LCA numerical model for mountain hut and specific LCA numerical models for each mountain hut with all specific inputs. In this paper the detail information for energy and mass balances for Pogačnikov Dom hut will be presented. Data included are fossil fuel consumption, electricity consumption and generation, biomass consumption, transportation type and distances covered which contribute to the environmental impacts of mountain hut operation during one year. According to these that one implementation action will be applied and compared emissions of CO_2 and NO_x before and after implementation.

METHODOLOGY IN THE STUDY

In the first part of the study the basic methodology used to collect all the data is the survey based on specific questionnaires and interviews of huts owners. In the second part the basic LCA numerical model will be set up to get general overview of all possible inputs and outputs. In the numerical model all processes, virgin materials, transport types and distances and other flows important for mountain huts in the LCA study are included.
On the basis of data provided with LCI tables for Slovenian hut (Pogačnikov Dom) LCA numerical model with all mass and energy balances are set up. Furthermore the CO_2 and NO_X emissions are calculated for transportation and operation phase of the Pogačnikov Dom hut. This preliminary calculation study will serve as a data source for more detailed LCA study later in the project.

Technologies reviewed in the study are just currently used technologies and energy carrier in the mountain hut. From operational point of view just the integral data (average working hours, yearly fuel consumption, number of transportations of the fuel to the huts, etc.) for one year average is important as an input data for further LCA study. In this point the operation dynamics is not needed. This study will deliver the basic list with the type and power of technology used, m
ain energy carriers, and basic operational characteristics. The Slovenian members in Life+ Sustain Huts are: Slovenia Mountain Partnership (PZS), Slovenia's Hydrogen Technology Center (CONOT) and University of Ljubljana (UL).

Huts involved in the study

Life+ Sustain Huts is a demonstrative project which aims to reduce environmental impacts in natural habitats by implementing novel and original renewable energy based solutions in mountain huts. The mountain huts within the project are located in 4 different European countries. Particularly, there are 2, which are located in Slovenia (Kocbekov Dom and Pogačnikov Dom); 5 mountain huts located in Spain, four involved in the project (Bachimaña, Llauset, Lizara and Estós) and another one will be included proximately (Montfalcó); 1 in Italy (Refugio de Torino) and the most recent one in France (Refuge D'Ayous). In this study we will analyse Slovenian mountain hut Pogačnikov Dom.

The Pogačnikov Dom (Figure 1) is located in Triglav National Park to 4 km from Slovenia's highest mountain Triglav, it is perched on a small hilltop at the altitude of 2050 m on the peak of Kriški podi Kriški podi and also is surrounded by other six peaks: Bovški Gamsovec, Križ, Stenar, Razor, Planja and Pihavec. There are marked routes in order to can access to all of them. In the Figure 2 is shown the location of the hut. Latitude of the hut is 46,401965 and longitude is 13,800577.

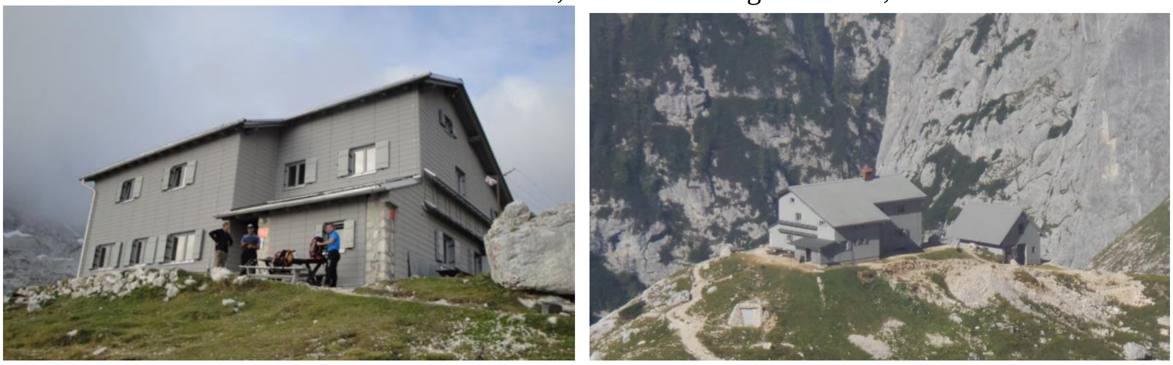

Figure 1. Pogačnikov Dom, Slovenian hut

The hut was built during 1948 and 1951, though it was renovated and extended in 1973. After that, a cargo ropeway was constructed (nowadays is upgraded since 2003), while in 2004 the roof of the hut was renovated. Pogačnikov Dom is located in Slovenian Alps and it is usually open 3 months per year, from mid-June to mid-September. Dimensions of the hut are 15.5 x 11.5x 7.5 m, capacity is for nearly 80 people, but the average accommodation per day is 28, besides 3 people work there. Pogačnikov Dom has diesel and gasoline generator, PV panels with batteries for electricity generation and wood stove for heat generation. Wood burning oven is use for cooking.

Figure 2. Location of Pogačnikov Dom in Slovenian Alps

ENVIROMENTAL IMPACT ASSESSMENT

Environmental impact assessment in this study was done with the life cycle assessment (LCA) methodology, which follows the ISO 14040 and 14044 standards, [8,9]. The environmental impacts have been evaluated according to the CML 2001 method for global warming indicator (GWP), [10].

The goal and the scope of the LCA study

The one of the goals of Life+ Sustain Huts project and also this study is to make detailed life cycle inventory (LCI) tables for all mountain huts (Pogačnikov Dom hut in this study). The scope of the study are ''gate to gate'' which include all emissions to air, soil and water during operation of the Pogačnikov Dom and transportation of the fuel. Functional unit used will be 1kWh of energy generated (electricity, heat) that will enable relative comparison of different huts separately for electricity and heat production

Life cycle inventory (LCI): mass and energy balance

Below it is detailed specification for Pogačnikov Dom with all information in tables, where operational characteristics are summarized. The aim is to reach the maximum information about the technologies installed on the hut, and the current state of hut, such as dimensions, average of visits per day, capacity of accommodation, as well as the surroundings, where the hut is located in order to analyse the possibility to install new technologies or improve current ones. All data are for 1 year operation (3.5 months – Jun- Sep).
The technologies for electricity generation in the hut are gasoline and diesel generator with 1,37 kW PV system with batteries (storage) and converters (Table 1). For the heat generation, the hut uses a wood stove and for cooking wood burning oven (Table 2). The fuel consumption for hut operation is 733.82 kg of diesel, 74.88 kg of gasoline and 20 m^3 of biomass (firewood) per year (Table 3).

Table 1. Technologies used for electricity generation in Pogačnikov Dom

Electricity sources	Brand / type	Time	m^2	Installed power	Max efficiency	Electricity generation
Diesel generator	Nutool NDGS5000T	401 h	/	4.2 kW	19 %	1684.2 kWh/year
Petrol generator	Honda EC60002k	45 h	/	4.5 kW	22 %	202.5 kWh/year
PV panels	BP 255	/	4.32	1.37 kW	15 %	1347 kWh/year
Batteries storage	TAB 8 OPzS 800 Ah (2V*8)	/	/	115.2 kWh ~19200	/	/
Electricity consumption						**3233.7 kWh/y**

Table 2. Technologies used for heat generation in Pogačnikov Dom

Heat sources	Installed power	m^3	Efficiency	Energy generation in 1 year/kWh
Wood stove	8	8	/	36167 kWh
Wood-burning oven	5	/	70 %	
Energy consumption				**36167 kWh**

Table 3. Fuels consumption per year in Pogačnikov Dom

Fuels – consumption per year	Type of fuel	Used for	m^3	Mass kg
Liquid fuel	diesel	Electricity	0.882	733.82
Liquid fuel	Petrol 95	Electricity	0.09	74.88
Biomass	firewood	Heat	20	/

For accessing to the hut the only way for the visitors and employees is by foot. While for transporting the goods and fuel they use their own cargo ropeway (500l of diesel per year) and van (1920 km/year and avg. consumption: 15l/100km). Helicopter transport is hired only for heavier cargo, such as renovations or modification of the hut. Helicopter transport is excluded in this study.
According to all LCI analysis information a general LCA model for mountain huts are set up with all possible inputs/outputs:

- Fossil fuel consumption due to electricity generation.
- Fossil fuel consumption due to heat generation.
- Electricity consumption in the case of grid connection.
- PV electricity production in the case of currently installed system.
- Heat production from wood stove.
- Transport done with helicopter.
- Transport with cargo ropeway – diesel/electricity consumption for power.
- Transport done with cars, vans, trucks and other technologies (fuel supply, waste,..).
- Waste management and waste processing.
- Human resources and maintenance of mountain huts.

The general LCA model developed within task C5.2 [11] Life+ Sustain Huts project are divided in two parts: one for electricity production (presented in Figure 3) and other for heat production (presented in Figure 4).

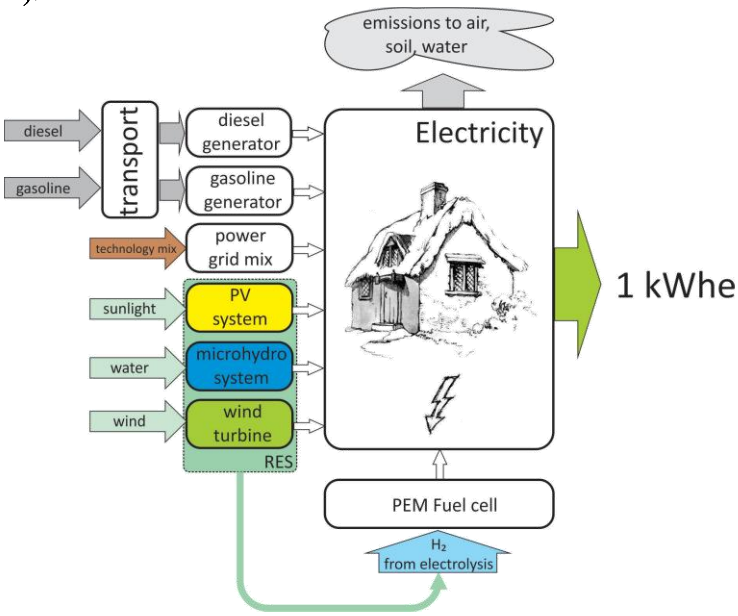

Figure 3. General LCA model for electricity production

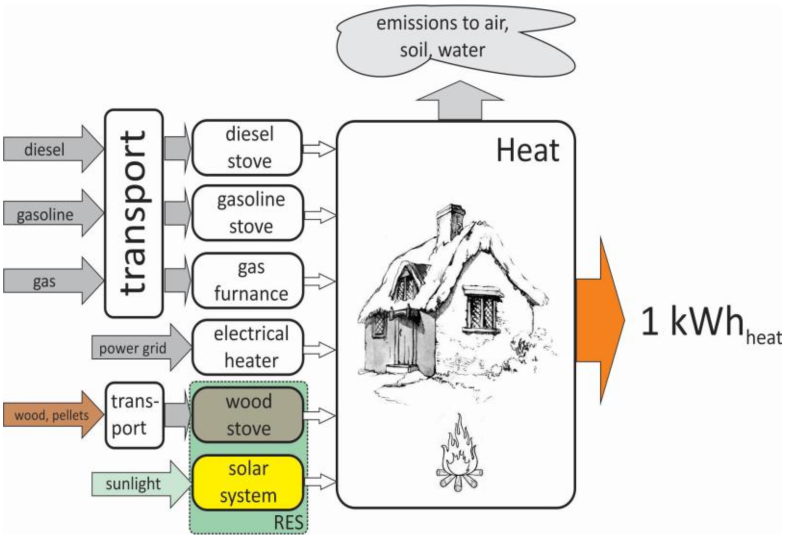

Figure 4. General LCA model for heat production

This approach with separated models for heat and electricity will be used because of easier comparison of environmental impacts before and after different interventions and changes in technologies for specific hut. Data used in the model are for the period of 1 year. In the case of environmental impacts before and after the project for specific hut, the overall energy generation will be included that will provide absolute results useful just in the case of single hut impacts evaluation.

One of the goals of this assessment is to see if we can with the implementation of new technologies achieve lower or almost zero environmental impact and more sustainable operation of mountain huts. For Pogačnikov Dom the installation of new PV panels (5.5 kW) and elimination of diesel and petrol generator are considered in this study. Boundary conditions in this study are:

- Transportation: van and cargo ropeway.
- Operation (electricity generation with diesel and gasoline generators).
- Operation (heat generation with wood burning oven).

Life cycle impact assessment methodology (LCIA)

After goal and scope has been determined, data has been collected, an inventory result is calculated. This inventory result is usually a very long list of emissions, consumed resources and sometimes other items. The interpretation of this list is difficult. An LCIA procedure is designed to help with this interpretation.
According to the CML2001 LCIA method the Global Warming Potential (GWP [kg CO_2 eq.]) midpoint indicator was used to compare CO_2 emissions per 1kWh of produced electricity/heat with different fuel sources. Furthermore the main goal of this study was calculate the reduction on environmental for (CO_2, NO_x) emissions before and after the implementation action which are planned for Pogačnikov Dom : Non-operational diesel and gasoline generators, installation of additional 5,5 kW PV panels and transport optimization (20% reduction of diesel consumption).

Values for CO_2 emissions was gathered from CO_2 emissions factors of German Environment Agency and International Energy agency [12,13] per 1kg of fuel and for NO_x emission data for transportation (helicopter, van and cargo ropeway), electricity and heat generation was gathered from Estimation of NOx emissions from fossil fuel combustion [14,15]. Used values for emissions per 1 kg of fuel are:

- Diesel: 3,162 kg CO_2/kg 0,0392g NOx/kg
- Gasoline: 3,189 kg CO_2/kg 0,0342g NOx/kg
- Biomass: 0 kg CO_2/kg – biomass are considered as CO_2 neutral, 0,009g NOx/kg

According to all mass and energy balances for Pogačnikov Dom calculation was done according to calculation methodology described above for different fuels (diesel, gasoline and biomass) and phases of the life cycle.

RESULTS AND DISCUSSION

The observed hut in this analysis relies on fossil fuels as main energy source for electricity and heat generation. The case study presented here is performed for Pogačnikov Dom in Slovenia with 3233 kWh of electricity and 36166 kWh of heat consumption per year (from mid-June to mid-September). Electricity is generated from PV system, diesel and gasoline generators and heat from firewood. Operation of the hut requires transportation of food, energy carriers, staff and in some cases also water to the hut. In the case of Pogačnikov Dom cargo ropeway driven by diesel engine is used for transportation and the consumption is 420 kg of diesel per year. The transportation with the van is also included and it is in average 1920km per year (15l of diesel per 100km). All mass and energy balances are presented in Figure 5 below as LCA model for Pogačnikov Dom before implementation actions (current status).

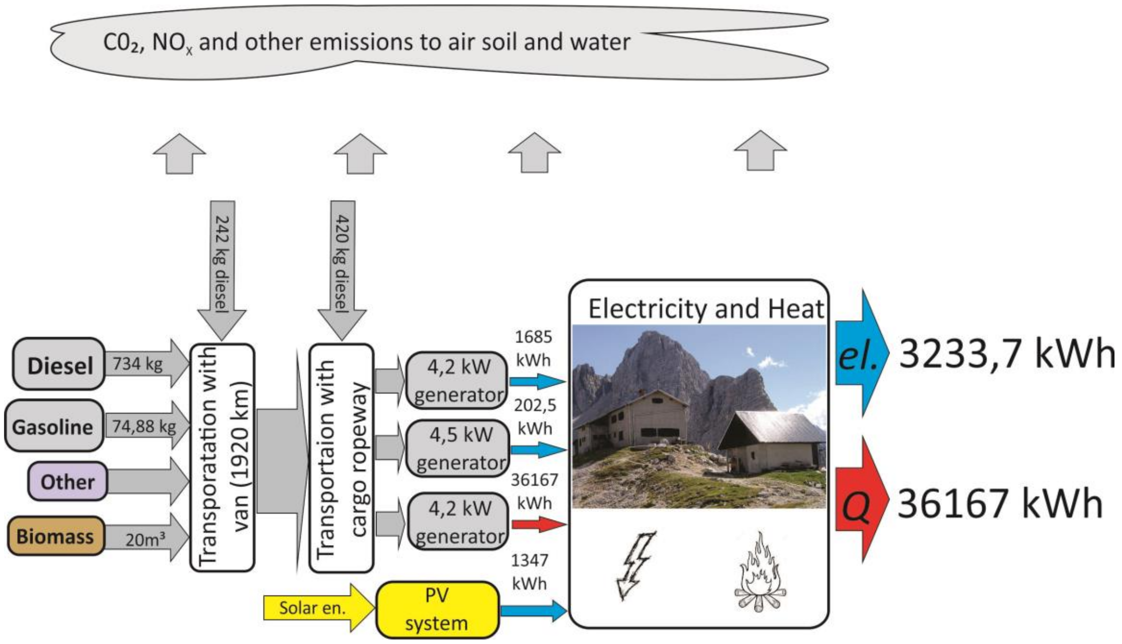

Figure 5. LCA numerical model with mass and energy balances for Pogačnikov Dom hut

According to current status and used fuels for 1 season (3,5months) hut operation the emissions emitted are 4678 kg of CO_2 and 65,9 kg of NO_x per year. The main contributors to the environmental impact are diesel generator and Cargo ropeway. Gasoline generator has small environmental impact because of lower consumption of the fuel and less operational time. Emissions caused by transportation are 2118 kg of CO_2 which represents 45,3 % of all emitted emissions in this study, the rest belongs to operation due to electricity generation (54,7 %). Similar ratios are at NO_x emissions where the highest value comes from diesel generator and cargo ropeway but here is also evident that heat generation contribute 15,8 % to NO_x emissions. Transportation contributes 38,4% and electricity generation 45,8 percent. From these results we can conclude that the highest environmental impact for CO2 and NOx emissions from Pogačnikov Dom comes from electricity generation and transportation.
Calculation of emissions after the implementation action, installation of additional 5.5 kW PV panels, removing diesel and gasoline generator and optimizing the transport, shows high reduction of CO_2 and NO_x emissions in Figure 6 and 7 respectively.

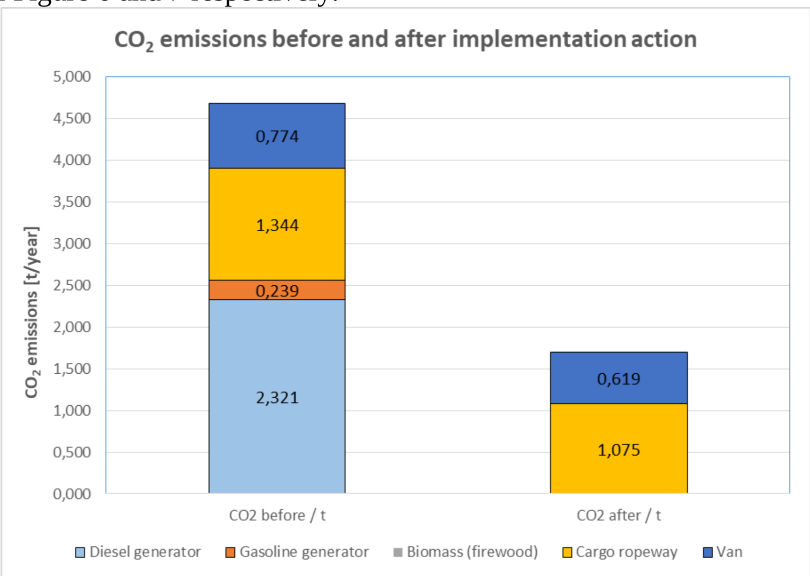

Figure 6. CO_2 emissions emitted during one season of operation for Pogačnikov Dom

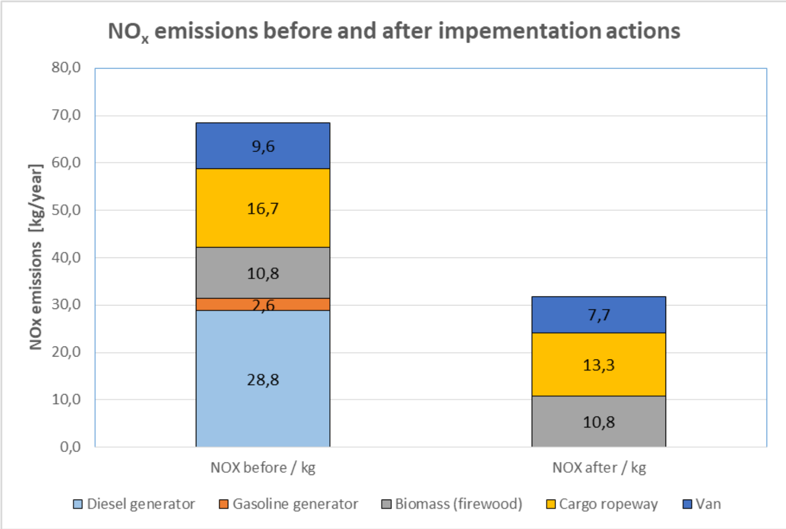

Figure 7. NO_x emissions emitted during one season of operation for Pogačnikov Dom

The first assessment of the emissions gives us just below 5 t of CO_2 and almost 66 kg of NO_x for operation time of 3.5 months (one season operation). With the investment that is planned in 2018 of 5.5 kW PV installed the fossil fuel driven generators will be put out of operation and reduction of emissions is expected to be from 50 % to 60 % in CO_2 emissions and around 50 % in NO_x emissions. In this analysis the overall emissions for CO_2 and NO_x are 64% and 54 % respectively.

Komentar GWP

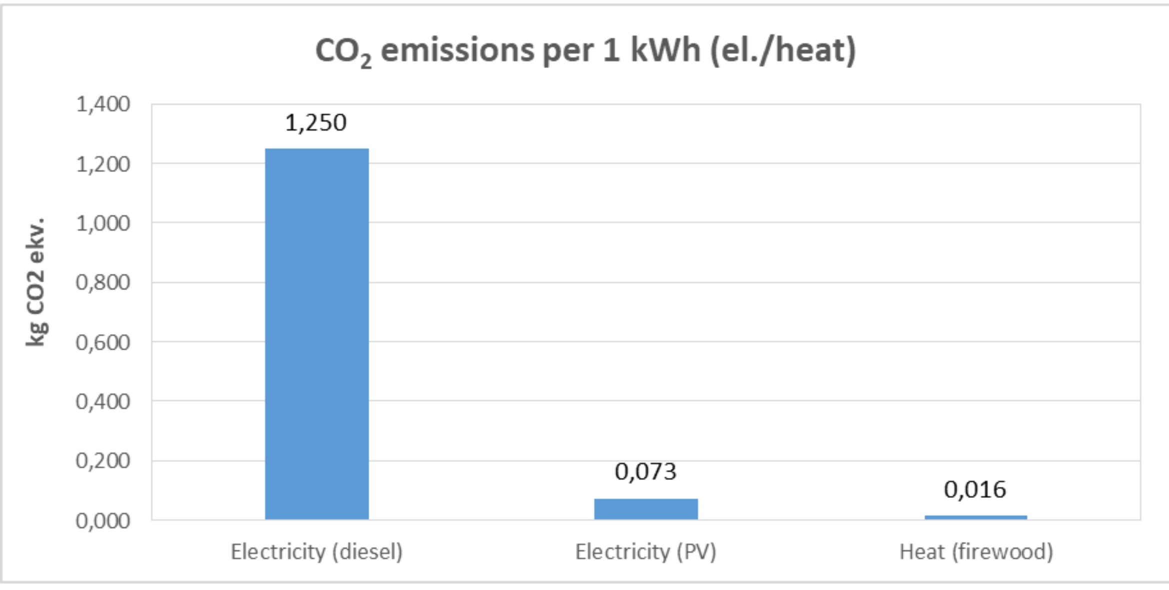

Figure 8. GWP (CO_2 eq.) for produced 1kWh of electricity (PV, Diesel generator) and heat (firewood)

CONCLUSION

It the case of mountain huts operation big improvements are possible in terms of emissions reduction because all huts currently generate electricity/heat from fossil fuels. This reduction is of great value since mountain huts are located mainly in very sensitive parts of nature and in the case of Pogačnikov dom in Natura 2000 protected region. It is shown that with basic investments, some optimization procedures of the transport and with additional education of the staff working in the hut, reductions of around 50 % in CO2 and NOx are possible

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