



» The project was co-financed by the European Commission through the European Agricultural Fund for Rural Development (EAFRD) «

Revitalizing water mills to obtain renewable energy

PRELIMINARY DESIGN CONCEPTS FOR REVITALISATION OF RIVER MILLS AND INSTALLATION OF SMALL HYDROPOWER PLANTS IN BELA KRAJINA REGION OF SLOVENIA

Background

The mills along the Bela Krajina rivers are an important part of Slovenian cultural heritage, which has sadly been deteriorating over time. This is because they no longer function in their role as mechanisms (mills/saws) in the larger water-system scheme. Cultural heritage of its kind is slowly disappearing under the moss and debris of the rivers Kolpa, Krupa, Lahinja and Dobličica, which is why this is our last chance to formulate a comprehensive approach to solving this problem.

The project “**Revitalizing Water Mills to obtain renewable energy**” was co-financed by the European Commission through the European Agricultural Fund for Rural Development (EAFRD), under the LEADER approach, and provided for in the 2010 Annual Implementation Plan of the Dolenjska (Lower Carniola) and Bela Krajina (White Carniola) Local Action Group. The project was implemented by the Municipality of Črnomelj (Lead partner) and in close cooperation with the following partners: the Municipality of Metlika, the Municipality of Semič and the Nature park Kolpa river.

They posed the question how best to take advantage of the energy potential of the Bela Krajina river systems and in what way they might support the many mill owners that already devised the initiative for the renovation of the mill objects. The project gave rise to many ideas, answers and visions for growth, but also opened up many new questions: e.g. which locations mentioned in the project have seen activities continue after the basic concepts were formulated and are now even closer to realizing the set goals? The project has also inspired some other mill owners at locations not originally included in the project to start thinking about renovating their buildings.

Actors

The project was dedicated to the wider interested audience as well as responsible companies in the context of the ministries and other institutions that have a part in the procedures related to acquiring the correct permits required for renovations and concessions for the construction of small hydro generators. The project is intended to connect as many mill owners over the entire area of the three counties that were ready to invest in the revitalization of the mills and the harnessing of energy with Small Hydropower Plants (SHP). With a unified and a synchronized editing approach regarding spatial planning, different services would be combined across the river meander, speeding up the procedures and help interested investors realize their progressive visions. This type of revitalization of the objects would not only constitute a continuation of the rich cultural heritage here together with a scheme for the rational use of a clean, renewable source of energy, but would also connect individual locations into a cohesive comprehensive story about respecting the culture of our ancestors that is both interesting to us and also serves as a useful teaching tool for younger generations. New programs and content on said locations (museum activities, heritage exhibitions, milling, baking, path-finding, overnighting in mills etc.) would, in connection with current programs and activities (nature recreation, swimming, water sports, camping etc.) aid in the development of tourism both in Bela Krajina and Slovenia as a whole.

Workflow

The basic idea behind the revitalization of the mills along the rivers of Bela Krajina and the installation of SHPs is based on the results of previously conducted activities within the larger context of the whole project (**Revitalizing Water Mills to obtain renewable energy**) and in particular, the reports “Okoljski vidiki in usmeritve za ustrezno revitalizacijo mlinov na belokranjskih vodotokih in umestitev malih hidroelektrarn, Oikos, svetovanje za razvoj, d.o.o., maj 2012”. A total of 14 objects were included in this project, 11 of them situated on the river Kolpa, 2 of them on the river Lahinja, and one of them on the river Krupa. The mills are located in protected areas; where they lay inside nature conservation areas and partly in Natura 2000 areas the objects are largely protected as

cultural heritage, with some of them also considered cultural monuments. The areas near the rivers are in most cases also flood areas, which presents a considerable challenge in spatial planning and significantly impacts the decision which technology to use to harness the renewable resources that the rivers represent. The objects are located some distance from the local villages and areas of so-called dispersed settlements/housing, which explains why there has not been any communal access to them; as it is the locations are only in use during the summer, when tourists fill up the river banks and use the mills as storage spaces for their boats.

Baseline rules

On the basis of previously conducted studies it was important that we follow these Baseline rules in executing our set goals, which are as follows:

- renovate/replace already set objects (mills, dams)
- ensure ecologically acceptable river flow
- adjust flood threat solutions
- ensure safe dam river flow for water life and river sediments
- prevent damaging fish and other aquatic life
- ensure the safety of river users (swimmers, boaters, fishermen)
- ensure compatibility with other recreational uses of the river – swimming, boating (safety of swimmers, possibility of dams, entry and exit points), and fishing (prevention of harm to fish and river life)

These rules related to the inputs related to the environment – water, nature/biodiversity and cultural heritage – were closely developed at every location. Mills are intended to be renovated, renewed or reconstructed, with appropriate programs and activities initiated, and next to them small hydro-power generators. Some objects that are now ruins would only be protected from further deterioration. Specific locations were analyzed, measured and the record drawings of the buildings were made. All of it based on the archived material provided by Bela Krajina Museum Metlika or mill landlords themselves was analyzed.

Program basis

In the process of analyzing the locations and objects it became apparent that certain locations have immediate potential for use as a source of renewable energy, due largely to the state of the dams and troughs and issues related to accessibility and communal equipment. At other locations the siting of SHPs is contingent on questions of sanitation and the state of dam reconstruction, and the construction of communal canals and similar. Construction of SHPs at two locations where protected objects of cultural heritage are concerned turned out to be an inappropriate solution – and location is important from the perspective of representing cultural heritage, preserving milling traditions (plenty of preserved technical content) and preservation of the natural environment. In these cases the use of a water wheel for the grinding of grain (but not energy production) was recommended. In conversations with the owners different ideas and priorities arose: at some locations higher energy production using acceptable technological solutions took priority, which would in the future require raising the financial resources required for the renovation of the mill. In some cases investors didn't express any intent to open the object to the public; with that in mind the suggested program is only offered as an option, and the owners will likely renovate the projects according to their own wishes and requirements.

SHP technology

Technical solutions for the siting of SHPs were decided on the basis of available hydrological data, which was then matched with data from professional institutions working in nature preservation and cultural heritage preservation; and from conversations with building owners and their problems and concerns with development. On the basis of all of the above hydrological data and similar, SHP power output was rated for individual locations. Concrete technical solutions for individual locations were prepared with the side of SHP design professionals from Germany. On the basis of these concrete technical solutions guidelines on how the procedure might go forward were also developed. The final decision regarding the technology employed and the program and activities in/at the object was of course left with the owners, whose interests are guided largely by financial questions and investment opportunities. The basic draft proposals merely served to give owners a general idea of the project, which they could use in the initial planning and later, construction of the object; or with which they might develop the project further and upgrade it.

Locations of discussed river mills with selected SHP technology

<i>no.</i>	<i>Mill location</i>	<i>Selected technology</i>	<i>Programme design concept</i>
	Kolpa River		
1	Madroničev mlin (Madronič's Mill) with sawmill, Prelesje 10	Archimedes screw - 2x + waterwheel	Tourism, museum, flour milling
2	Radenski mlin (Radenci Mill), Gorenji Radenci	Archimedes screw - 1x	Tourism, accommodation, sports
3	Brečka malenca, Breg pri Sinjem vrhu	Waterwheel, millwheel	Culture, education
4	Mill, Otok pri Vukovcih	Archimedes screw - 2x	Accommodation, sports
5	Benetičev mlin (Benetič's Mill), Vinica 69	Archimedes screw - 1x	Flour milling
6	Mill at Vidine, Preloka 49	Archimedes screw - 2x	Heritage presentation
7	Kuzmin Mlin (Kuzma's Mill) with sawmill in Pobrežje pri Adlešičih 4	Waterwheel, sawmill wheel	Sawmill, flour milling, tourism
8	Fortunov mlin (Fortun's Mill), Krasinec 23	Archimedes screw - 2x	Tourism, accommodation
9	Mill, Otok 24	Archimedes screw - 1x	Accommodation, sports
10	Mill, Križevska vas 64	Archimedes screw - 1x	Museum
11	Mill, Želebej	Archimedes screw - 2x	Culture, multi-purpose facility
	Lahinja River		
12	Homestead at Butoraj 6	Waterwheel	Education, tourism
13	Trček homestead, Križevska vas 80	Archimedes screw 1 + waterwheel	Heritage presentation
	Krupa River		
14	Mill, Moverna vas 1	Waterwheel	Tourism, education

Archimedes screw

SHP technology based on the Archimedes screw is an extremely viable option for small heads and moderate flows that are characteristic for all watercourses in Bela Krajina, demonstrating high efficiency and excellent operational characteristics even at small loads. The system is also fish-friendly; the screw allows the fish to pass downstream through the auger unharmed, and even tree branches can pass through the screw without problems. The noise generated by the rotating auger is not significant as the auger rotates at the speed of the water current; the noise caused by the generator is more substantial. Considering the flooding history of the discussed locations along the Kolpa River it is necessary that a correspondingly watertight SHP mechanism be installed; this mechanism may be flooded for a certain period upon prior suspension of the SHP.

As there is no precise data available for these locations, uniform baselines have been defined for individual watercourses with consideration of the general hydrological characteristics of the discussed watercourses, available concrete information and field examinations. For the Kolpa River some key parameters have been defined for the exploitation of the water potential, such as water flow through the SHP, which may not exceed 5 m³/s at any location, and the hydraulic head, which is estimated, based on a singular height of all dams on the Kolpa River, at 1.20 m (later up to 1.40 m) for all locations.

The flows on the Krupa River and the hydraulic head (below 1.00 m) are too low for an Archimedes screw to be economically viable. The situation on the Lahinja River is similar. The only exception is the location in the lower part of the Lahinja course, immediately before the outflow into the Kolpa, where the estimated hydraulic head reaches 1.10 m. These parameters provided the basis for the framing of two options for an SHP, with a single or double Archimedes screw (e.g. TIP CS, WS2300, produced by the Rehart GmbH company), depending on the width of the existing chute/trough.

Waterwheel

The waterwheel is one of the oldest hydraulic machines known to man and has been used since antiquity. The first waterwheels were made of wood, but as the principles of potential and kinetic energy were not fully understood at the time, they were not particularly efficient. With the development of hydraulic engineering and new materials the shape, power output and efficiency of water wheels has improved substantially. The waterwheels used on watercourses in Bela Krajina are undershot wheels. The water enters the wheel below the axis level. This type is suitable for very low heads ranging from 0.5 to 2.5 m and large flow volumes ranging from 0.5 to 0.95 m³/s per metre width.

Various tests have shown that waterwheel efficiency is high and relatively constant throughout its load range. This can be attributed to long-term development, improved manufacturing technologies and maintenance. Consequently, waterwheels may still represent a viable alternative to more complex turbines, especially in watercourses with low heads and moderate flows.

Before a waterwheel is installed into the existing mill troughs/chutes a static examination of the existing facilities should be made and static rehabilitation of the facilities conducted in line with the assessment findings. The image and dimensions of the waterwheels are adapted to the traditional model. The wheel diameter is not increased as the wheel axis still depends on the existing openings in the water-facing facade of the facilities. The width of the wheels may be extended, but remains limited to the width of the existing trough. Waterwheels are made entirely of wood or as a combination of wood and metal. The blades are made of wood. The retaining construction for the wheel is to be made of stone. Considering the flooding history of the selected locations along the Kolpa River it is necessary that a correspondingly watertight SHP mechanism be installed in the interior of the facilities, directly on the wheel axis.

Coordination of concept designs

Concept design proposals were presented and coordinated with individual owners of the studied mills, with them actively involved also in the final stage of the "Revitalizing water mills to obtain renewable energy" project. The proposals were also presented to the participating municipalities and professional institutions competent for nature conservation and protection of cultural heritage. Their comments and proposals were used to supplement and improve the concept designs.

Two of 14 investors decided to continue with planning in collaboration with our team from the company SAPO d.o.o., which for this purpose is collaborating with the Ambiens d.o.o. company (building structures). Both locations are presented on posters.



Author group, photographer: Nande Korpnik, 2014

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Lead partner: Municipality of Črnomelj

Project partners: Municipality of Metlika, Municipality of Semič and Nature park Kolpa river.