Oil Shale, 2005, Vol. 22, No. 2 Special
pp. 233-241
ISSN 0208-189X

https://doi.org/10.3176/oil.2005.2S.15

RESOURCE AND UTILIZATION OF ESTONIAN HYDROPOWER

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An overview of the Estonian hydropower resources and their utilization at present as well as prospective for the future are presented in this paper. A short overview of advantages of small hydropower stations and related issues is given. Some technological aspects are treated briefly.

Hydropower Resource

There are over 7,000 rivers and streams in Estonia but most of them are short, and poor in water: about 420 rivers are over 10 km in length and only 10 of them (Võhandu, Pärnu, Põltsamaa, Pedja, Kasari, Keila, Jägala, Navesti, Emajõgi, Pedetsi) have the length over 100 km. Discharge of less than 50 rivers exceed 2 m^3/s, and only 14 rivers have discharge over 10 m^3/s. The most watery rivers are the Narva River (average discharge in the mouth nearly 400 m^3/sec), Emajõgi (72), Pärnu (64), Kasari (27.6), Navesti (27.2) and Pedja (25.4).

Estonian topography is relatively flat, and rivers have small average slope. So the energetic potential of watercourses is rather moderate. Nevertheless, there exists a number of suitable small-scale hydroelectric sites (i.e. river segments with suitable slopes for making use of waterpower).

According to Estonian Encyclopaedia the total theoretical hydropower potential of Estonian rivers is about 300 MW. Distribution of the theoretical resource of Estonian watercourses by catchment areas is presented in Fig. 1.

The total technically feasible potential by different assessments is about 30–60 MW [1]. Utilization of this resource would enable:

- to produce 250–400 GWh of electric energy;
- to cover 2–5% of the overall demand;
- to save 0.2–0.5 million tons of oil-shale per year;
- to reduce the pollution burden, on average, as follows: fly ash by 1500 t, SO_2 by 1,300 t, N_{ox} by 150 t and CO_2 by 75,000 t per year.

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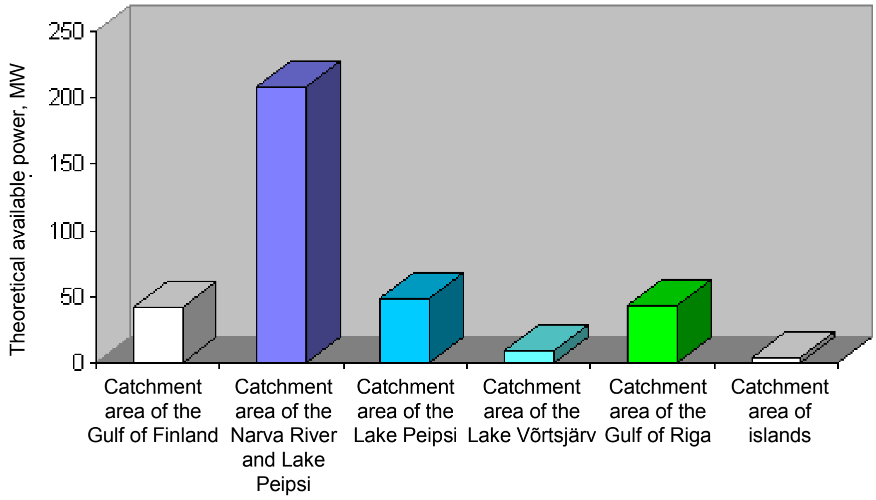


Fig. 1. Distribution of theoretical hydropower resources of Estonian watercourses by catchment areas

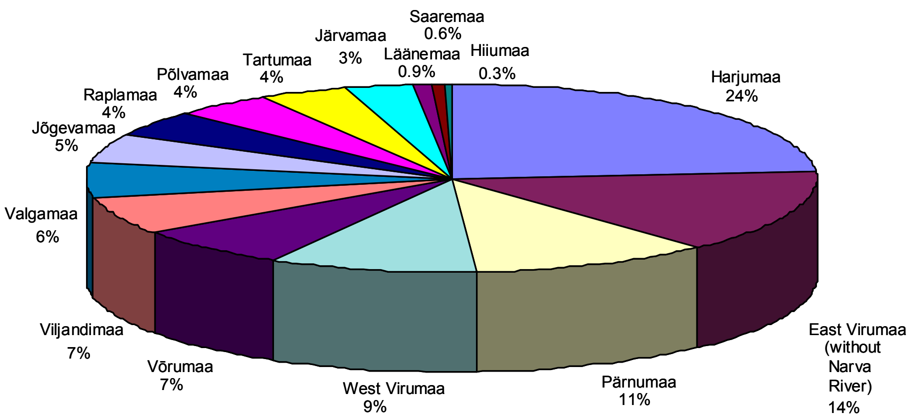


Fig. 2. Distribution of the technical hydropower potential of Estonian watercourses by counties

In evaluating Estonian waterpower resources it is rational to deal separately with the resource of the Narva River for the following reasons:

- The resource of the Narva River is comparable to the total resource of all other rivers and its harnessing might be of interest from the aspect of large-scale power generation;
- The resource of the Narva River is presently used by the Narva Hydropower Station (125 MW), which is owned by the Russian Federation. According to international customs, the output of a power station operating on a border river should be divided between the relevant countries in proportion to the part of the catchment area located on their territories.

Thus Estonia should have the right at least to one third of the output of the plant;

- On the river there is a substantial undeveloped resource – Omuti site with the capacity of 15–30 MW by different estimates;
- As Narva is a border river, its harnessing involves complicated political issues in addition to purely economic considerations.

In Figure 2 distribution of the technically feasible hydropower potential of Estonian watercourses by counties [1] is presented.

A Sight into the Past

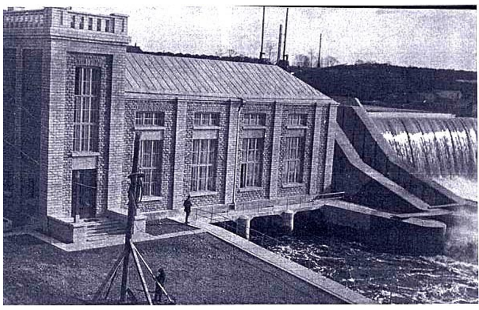
The earliest written records on watermills in Estonia stem from the 13th century. The first hydropower plants were commissioned at the end of the 19th century. Before World War II the share of waterpower in the energy balance was rather big: in 1936 the capacity of hydro installations made up to 18.2% of the total capacity of engines, and their energy production covered 28.2% of the overall demand [2]. There where 921 hydro turbines and water wheels with total capacity of over 27.5 MW in operation in 1940. The total capacity of hydropower plants was 9343 kW and their output, 28,770 MWh, made up to 28.6% of the total electricity production [3].

During the war most of hydropower facilities were destroyed. In years 1945–1950 many of former power plants were restored and some new ones were launched as well (in 1949 the total capacity of hydropower plants was 1,140 kW). Hereinafter the use of hydropower became extinct because it was considered to be unpromising due to extensive developing of oil shale power industry.

Present State

A new rise in utilization of hydropower resources of rivers began after the restoration of independence. In 1991 a former plant Saesaare on the Ahja River was restored, in 1993 former plants Leevaku and Kotka on the rivers Võhandu and Valgejõe, respectively, were restored. Henceforth the restoration of former power plants and reconstruction of former water mills is in progress.

At present over 20 small hydropower plants and a number of micro-plants (with capacity under 10 kW) with total capacity of 5.4 MW and with total annual production of 30,000 MWh in average are connected to electrical networks. The most powerful and up-to-date is the Linnamäe plant on the Jägala River put into operation in 2002 (Fig. 3). There are three turbines of the Finnish company Waterpumps installed in the plant with total capacity of 1.1 MW and with the average annual production of 6–7 GWh. Specific investment cost turned out about 30,000 EEK/kW.

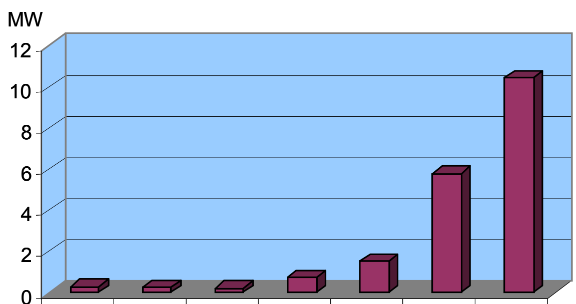


a

b

c

Fig. 3. Linnamäe hydropower plant: *a* – after commissioning in 1924; *b* – before restoration in 2001; *c* – after commissioning in 2002.
Source: http://roheline.energia.ee/re_pildid_Linnamae_HEJ.html



Year	1980	1985	1990	1995	2000	2005	2010
Total capacity	0.28	0.22	0.2	0.7	1.5	5.8*	10.5*

Fig. 4. Change of the total capacity of Estonian hydropower plants (* – forecast)

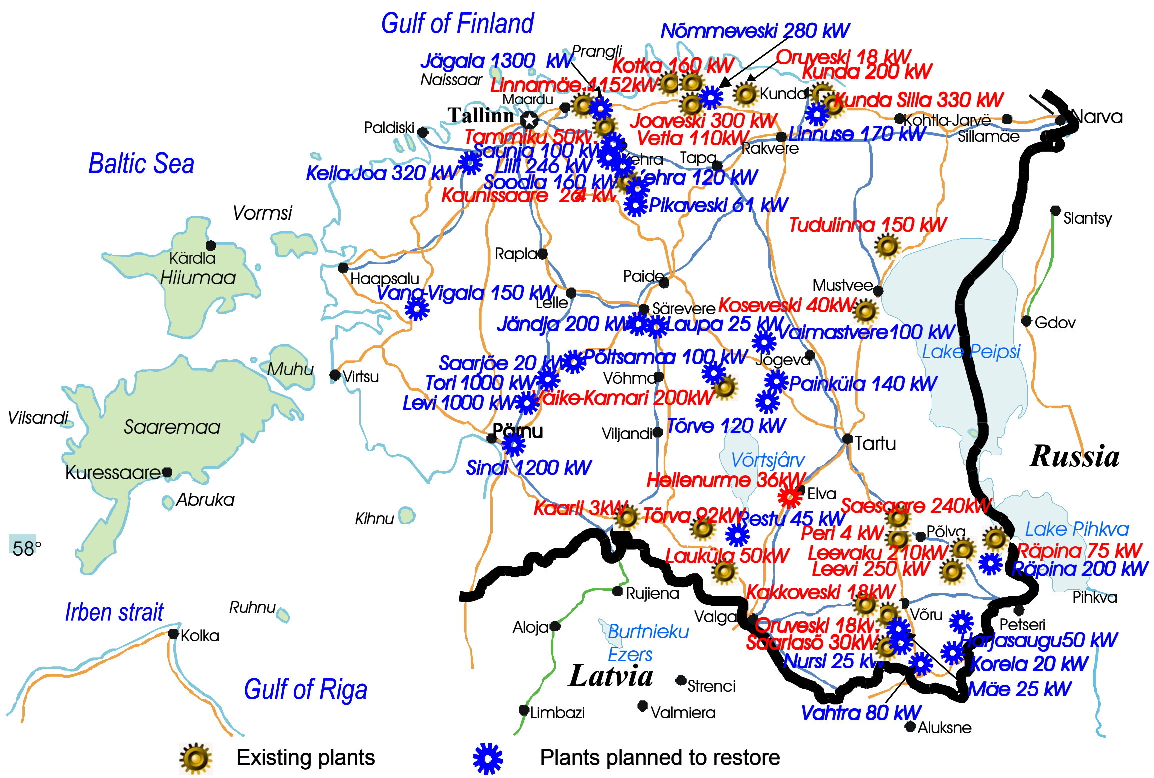


Fig. 5. Hydropower plants operating at present and planned to be restored in the near future

Several hydropower enterprises (Generaator Ltd., Estonian Water Power Ltd., etc.) are operating in Estonia at present. Estonian Power System, local authorities and a number of private entrepreneurs have shown interest in hydropower production. A web site with guiding materials for promoters of small-scale hydropower plants is opened in the Internet [4]; a short guide for designing of small-scale hydropower plants is published [5]. The average rate of commissioning of hydropower has been lately about 0.4–0.5 MW per year. Figure 4 illustrates the dynamics of the total capacity of Estonian hydropower plants in last decades.

Prospective for the Future

In the near future the restoration of 28 more powerful former hydropower plants and water mills with total capacity of 5.6 MW and total annual production of 34,000 MWh is planned. Besides, there are five former hydropower plants with total capacity of nearly 0.5 MW and total annual production of 3,000 MWh, which are worth restoring in forthcoming years. There are about two hundred former water mill sites suitable for restoration. Location of hydropower plants operating at present and planned to be restored in the near future is shown in Figure 5.

Advantages of Small Hydropower Plants

Small hydropower plant has a number of advantages, such as:

- Well-developed technology: small hydropower plants are simple, very reliable and with long life-time (usually over fifty years)
- Production costs are practically independent of inflation
- Small operation costs, nearly full automation
- Low capital costs and relative simplicity of construction works allow to restore and build plants in short time using low resources and applying simple technology by small non-specialized construction companies
- Small hydropower plants allow to reduce network losses and improve the voltage quality due to dissipated location
- Their connection to the grid does not cause serious problems
- In Estonia there are long traditions of small hydropower plants, many remained installations, and presence of interests in their reconstruction;
- Small hydropower plants do not waste resources – the water is still usable after flowing through the plant
- Advantages of regional development: owing to restoring of former hydro-installations, bridges and storage lakes will be repaired; leisure

activities, tourism and fishing opportunities will be extended and employment rate in counties will grow

- Disadvantageous environmental impacts are moderate. Vice versa – small hydropower plants level river flows, improve sanitary state of the river (water exchange, oxygen content of water), small storage lakes often make the landscape more expressive. The storage lakes will improve resistance of rivers to drought and cold periods – they will not parch up in summer time and freeze through in winter. So they guarantee life conditions for fishes and bottom fauna in extreme situations and avoid emptying of wells in drought periods

Disadvantages of Small Hydropower Plants

However, small hydropower plant has definite disadvantages as well:

- Dispersedness and limitedness of the resources
- Seasonality and weather dependence, however, substantially less than, for example, in the case of wind or solar power
- High investment costs per unit (1,000–5,000 US$ per kW) and relatively high operation costs. Nevertheless, the use of new corrosion-proof materials and new construction elements (inflatable dams, plastic penstocks, etc.), simplification and standardization of hydro sets (particularly immersible units with induction generators), implementation of modern control systems as well as continuous rise in organic fuel prices make small-scale hydropower in every respect more competitive. The best economic indices are obtained in cases of restoration of former power plants
- In the case of connection to a weak grid, certain problems with reactive power may arise; capacitor batteries should be installed in order to overcome them
- Influence of reservoirs is not always unambiguous: the water which is, on average, warmer lacks oxygen and may reduce the number of precious species of fish (grayling, trout) preferring cold water. To reduce such influence, fish-passes or fish ladders are required, but they need a good design and rather big construction costs
- Rise of water level may cause troubles in soil improvement
- Specific problems may arise if there are intakes for other purposes or a cascade of plants on the watercourse
- Possible disappearance of picturesque natural waterfalls. To maintain them the Finnish experience could be implemented. For example, plants located in such sites are closed in tourist seasons

- Possible mismatch to surroundings; to avoid this the construction of small hydropower plants needs an adequate design: earth or stone weirs should be preferred to concrete ones, closed channels and penstocks could be used, spillway weirs could be designed as natural rapids, etc. There is a good experience in West Europe as well as in pre-war Estonia
- Loss of land due to flood, but this can be reduced by construction of appropriate floodwalls
- High noise level; however, the use of sound barriers and modern equipment enables to reduce the noise level as much as possible
- Therefore, it is possible to overcome most of the disadvantages

Problems Related to Small Hydropower Plants

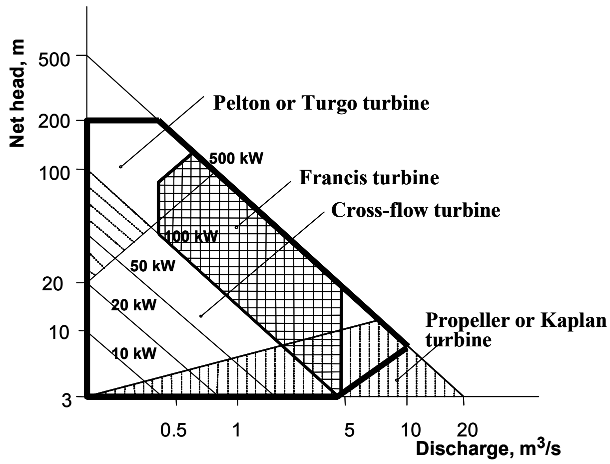
The main problems related to the restoration of former hydropower plants and construction of new ones in today's Estonia:

- Relatively high specific investment costs – the production cost of electricity will be relatively high (60–130 s/kWh for restored power plants and 85–170 s/kWh for most of new ones)
- Financing difficulties – due to relatively small requirements it is difficult to get long-term soft loans
- Scarcity of experience and know-how, difficulties in obtaining proper consultation
- Shortcomings in legislation – particularly in provisions regulating the use of water resources (including the water use in the case of a cascade of plants on a river). Clauses for access to the grid should be more transparent and explicit
- Unclear ownership relations in many cases
- Political obstacles in realization of the Narva River potential

Some Technological Aspects

As the heads in hydropower sites in Estonia seldom exceed 5–10 m, the most suitable turbine types for low head plants are propeller turbines as rather simple and cheap ones, and also more efficient but more expensive Kaplan turbines (Fig. 6). Cross-flow turbines are very simple but with low efficiency. At capacities of over 50–100 kW and heads 5–10 m more sophisticated Francis turbines can be used.

In today's modern plants Kaplan-type tube turbines as well as compact immersible units are preferably used. In micro hydropower plants reversible pump-turbines can be used as most simple and cheap ones.



As alternators asynchronous generators are most suitable – they are simple, reliable and cheap; they need no equipment for frequency and voltage control. At capacities up to 50 kW squirrel cage motors are suitable. Estonian hydropower plants are run-of river ones because they have no reservoir of sufficient capacity (except for Linnamäe plant).

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Received November 8, 2004