Water resources and wetlands, *Editors: Petre Gâştescu, William Lewis Jr., Petre Breţcan*
Conference Proceedings, 14-16 September 2012, Tulcea - Romania
ISBN: 978-606-605-038-8

HARNESSING OF THE HYDROENERGETIC POTENTIAL IN THE UPPER BASIN OF THE ARGES RIVER, ROMANIA

Laura Ana Mititelu
Administraţia Bazinală de Apă Argeş-Vedea, Piteşti, România, mititelulaura2000@yahoo.com

Abstract

Harnessing of water resources for various purposes (hydroenergetic, water supply, irrigation, fishing, leisure, etc.) represents an area of great interest, with broad implications for impact and environmental protection. Arges River Basin is a place with high hydroelectric potential, but also for other uses, especially, river Arges, was the target of several hydro facilities. Ever since the 60s of the twentieth century, by means of elaborate hydraulic works (dams and adducts) Vidraru lake has been one of the almost important hydro power in Romania (located in the Carpathian Mountains, dam 166 m, among the top 30 in the world, vol. 465 mil. cubic meters, underground hydroelectric power with a power of 220 MW, depending on hydro power and drinking water. Later, the development plan of Arges was extended, currently there are far downstream of Lake Vidraru (up to Golesti), still 10 lakes and 16 power plants. Beginning in 2011, following Romania's commitments to the European Commission related to green energy, a project was developed to build micro hydropower plants (MHPs), a project to harness the energy potential of the river tributaries in Vidraru Lake. So, there are proposed for development on the rivers Capra - 5 MHPS, the Buda - 4 MHPS and 1 MHP on the Otic, totaling an installed capacity of 14.7 MW that may be used by about 30,000 families. This paper presents the scheme of current harnessing and the proposed scheme, as well as the pros / cons related to green energy on this issue in recent years.

Keywords : hydroenergetic potential, green energy, MHPs, Vidraru

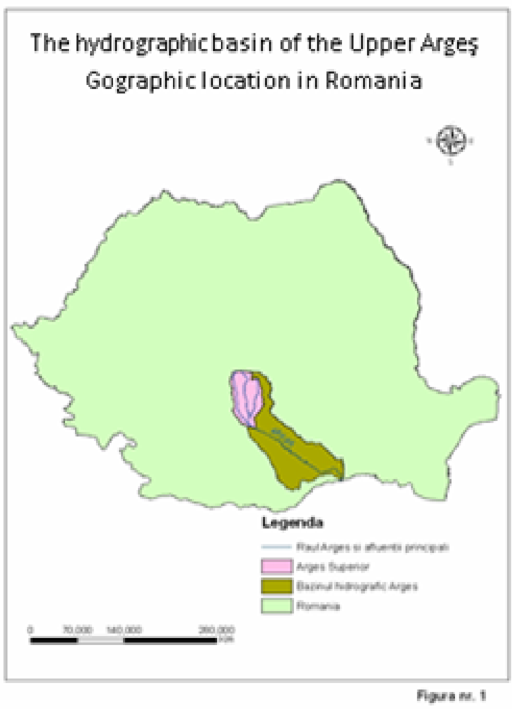

Figure 1. Geographic setting

Arges basin-territory on which the river collects its waters is located in the central-south of the country, ranging from north to south between the parallel of $45^o36'$ (at the top) and $43^o46'$ (in the inferior part) and to the west and east meridians $24^o30'$ and $26^o42'$ respectively. It flows into the Danube in the village Olteniţa, Calarasi. It is bordered on the north and north-west of the Olt river basin in the west and southwest Vedea basin, south of the Danube basin and the north-east and east basin Mostiştea and Ialomiţa.

In terms of altitude, Arges basin presents very varied altimeter indicators, including the highest mountains in the Carpathians (Fagaras Mountains, 2544 m) and runs up to about 12 m (Danube Valley). The basin is recognized as the basin with the highest altitudinal difference (Δh = 2128m). The analyzed area presents a diverse geographical landscape. Thus, from north to south there are all levels of terrain: mountains (over 2000 m), low and medium mountains (800-1000 m), hills and plateaus (300-800 m) and the plain. These are arranged in parallel strands, oriented east-west. The main morphostructural units crossed by the waters of Arges, from north to south, resulting from a long evolution are: Fagaras Mountains (takes about 29% of the basin), Getic Subcarpathians (44%), Getic Plateau (19%) and the Romanian Plain (8%).

According to "The Atlas of Water Cadastre in Romania» Arges basin has 178 cadastral watercourses, a total network length of 4,579 km (5.8% of the total length of the encoded network in the country), an area of 12,550 sqm (5.3% of the country) and an average density of 0.36 km/sqm (compared to the national average of 0.33 km/sqm^2):

- In the area of origin, Fagaras mountains, the river network density often exceeds 1.4 km/sqm. The average altitude mountain ranges in this area between 1200 and 1000 m, so that the average slope has high values (150 to 80 ‰).

- In the middle (between Arges and Gaesti) Carpathian hills, hilly and piedmont, the average altitude is around 800 m, and the hydrographic network density is 0.3 - 0.5 km/sqm and average slope has values of 10 to 15 ‰.
- The lower course runs from Ionesti (Find) and mouth and is characterized by a wide valley with numerous meanders with a drainage slope ranging between 9 and 6 ‰.

1. THE HISTORY OF HYDRO FACILITIES IN THE UPPER BASIN OF THE RIVER

The first attempts to achieve overall hydraulic works belong to some remarkable Romanian engineers since the early twentieth century. In 1934 Prof. Paul Dorin published his "**“Plan général d’aménagement des forces hydrauliques de Roumanie”.** Another Romanian hydrotechnician engineer, specialist in water management that has been mainly devoted to the problems of Arges river basin planning that he has led for more than 3 decades was Paul Solacolu. His first studies related to Arges river basin were developed in 1953 and they were the subject of the basin hydrotechnical scheme necessary to irrigate an area of 50,000 hectares. The novelty of these studies represented a concern for multiple uses of the resources of Arges not in the way it had previously been done in the studies focused exclusively on some remote uses (hydroenergetic potential recovery, or water supply). Water management plans in Romania also authenticated the concept of planning of waterways in multiple purposes to meet the complex needs of spatial planning in which a river basin was considered as a whole. Solacolu Paul was one of the main promoters of these ideas and he coordinated as a project manager the developing of Arges basin management plan. He helped to determine the location and functions of the water works of the Arges basin, mainly lakes and derivatives, designed to work with multiple uses. The first large-scale works in Arges basin began in the 60s with Vidraru harnessing, which having a height of 166.6 m is the highest dam in Romania. The promoting of the project started a conflict between the Ministry of Power that wanted the starting of the work planning of Lotru River (more efficient in terms of hydroenergy, but with limited benefits for other uses) and the State Committee of the Arges river that wanted the harnessing of the Arges river that had multiple advantages (power generation, water supply areas in Pitesti and Bucharest, irrigation and attenuation of flood), even if the parameters were energetically less favorable than the harnessing of the Lotru river. The complex scheme of harnessing of the Arges river in the upper course (up to Golesti) currently comprises a chain of 10 lakes (Vidraru, Oesti, Cerbureni, Curtea de Arges, Zigoneni, Vâlcele, Budeasa Bascov, Pitesti and Golesti) and 16 electric plants. To these there are added the branches (Doamnei River- Valsan-Arges and Topolog-Arges), 3 smaller accumulations (Baciu, Valsan and Cumpanita) and 2 hydroelectric power plants. (Valsan and Cumpanita) (Figure 2) .

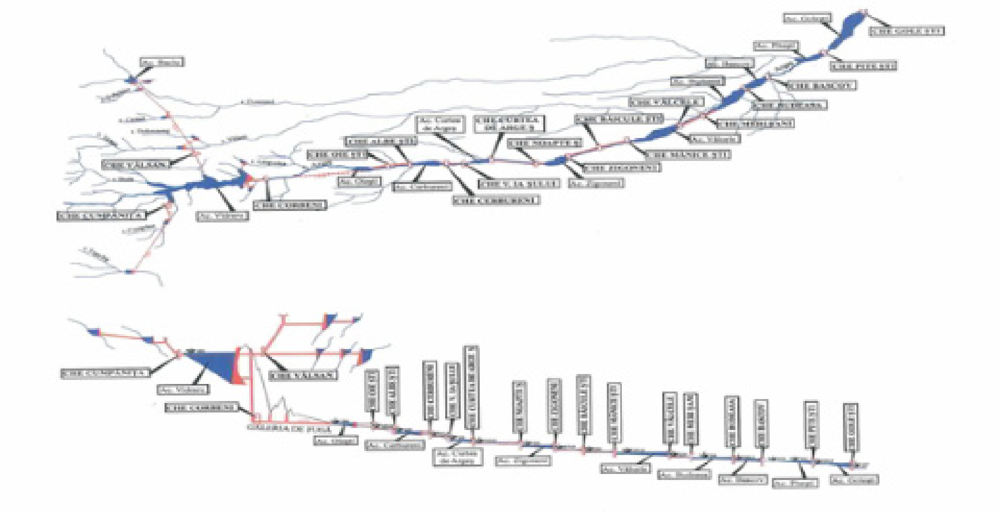

Fig. 2. The complex scheme of harnessing of the superior Arges basin

2. HYDROLOGICAL PARAMETERS AND TECHNIQUES OF HYDRAULIC HARNESSING OF VIDRARU

Vidraru hydrotechnical harnessing is a first major step in the complex harnessing of the river, its realization being appointed at the 1st of November 1960, for the production of electricity, the water supply of the cities downstream (Arges, Pitesti and Bucharest), irrigation, pisciculture and recreation. The hydrotechnical harnessing consists of: concrete dam behind which the lake was formed, main gallery of adduction, castle of balance, penstocks, underground hydroelectric plant (the first of its kind in the country, from which water is discharged through the gallery flee, unique at the time).

Fig. 3. Dam of the Lake Vidraru

Currently, the hydroenergetic system Vidraru is administered by S.C. "Hydropower plants" S.A., Branch Hydropower plants Curtea de Arges. It was administered in 1966 and it has complex features like: water supply, flood mitigation, energy production, irrigation, recreation. The main features of the accumulation of Vidraru are: the NNR area 870.0 hectares; NNR quota is 830 mdM; volume to NNR is 465 mil. cubic meters; volume 22 mil. cubic meters, flood mitigation; maximum dam height 166.6 m; type dam- double curvature arch. The hydroelectric plant made between 1961-1966, a small period for such a work , was the second hydroenergetic unit in the country, after the one at Stejaru-Bicaz from Bistrita River, to which however has different characteristics. During 1955-1960 at the proposal of the engineers Sipiceanu M. and S. Bogdan, the inflow was increased into reservoirs, capturing nine streams of the hydrological river basins of Topolog, Valsan and Doamnei River, all having an area of 457 sqm, the contribution the additional flow being approximately of 12.12 mc /s).

Table 1 Dams for water accumulation of Vidraru (Cr. Mateescu)

Nr. Crt	River	Captation area (Kmp)	Average flow (mc/s)
1.	Doamnei River	210	5.75
2.	Draghina Mare Brook	10	0.25
3.	Bradului Brook	3.1	0.06
4.	Cernatului Brook	42.6	1.14
5.	Vâlsan River	67.9	1.78
6.	Dobroneagu Brook	15.4	0.32
7.	Topolog	80.4	2.26
8.	Stan Valley	19.7	0.40
9.	Limpedea Valley	7.9	0.16
Total secondary captations		**457.0**	**12.12**
	Argeşul	286.0	7.55
General total		**743.0**	**19.67**

Thus, the average annual flow was increased from 7.55 mc/s to 19.7 mc /s by capturing the hydrographic network of Topolog, Valsan, Doamnei River and the direct rivers from the mountains. The waterfall, an important parameter in the hydroenergetic activity increased from 178.2 m to 324 m. Starting with this, the power installed in the plant increased from 30 MW to 220 MW (with 7.33 more). The inlet side, presented all in the form of galleries through which water flows gravitationally, were designed so as to enable the transportation of flows higher than the average captations. The eastern (Doamnei River-Vidraru) are 2.5 times larger, the western bypass (Topolog-Cumpanita) of 3.5 times and Stan Valley and Limpedea 5 times. This situation has been given by the requirement to use a bigger amount of annual stock water from these rivers. To achieve these secondary captations there were built three-arch dams of concrete: one on the Doamnei River (Baciu) between 1965-1967, with a height of 34 m and the NNR lake volume of 585 000 cubic meters; another on Valsan River , 25 m high and with 174 000 cubic meters volume of the lake, the third one is Cumpanita Valley of 33 m and volume of 288 000 cubic meters. These latter two were built in the period 1966-1968. The remaining 6 captations were obtained by making dams on stream flow thresholds as spillways, with sand traps that operate automatically. Downstream the Vidraru dam there was made a chain of small and medium hydropower plants. They are located either along the water and works with central-dam reservoirs or channels of accumulation, the so-called central-channel. Downstream Vidraru hydropower plant, on Arges valley from Oiesti to Golesti there are 15 hydroelectric power plants, between 7.5-15.4 MW installed capacity (Figure 2). They were activated in the period 1967-1968. It is found that at the 220 MW of the hydropower plant Vidraru and the 5 MW of the plants Cumpanita and Valsan there were added 187 MW, resulting in the entire Arges planning a total installed power of 417 MW. One notes that 71% of the production capacity belongs to Vidraru hydropower plant.

Fig. 4. Planning scheme to build Vidraru captation

3. THE "GREEN ENERGY" AND THE EUROPEAN LEGISLATION

The"Green Energy" or the renewable energy is the energy obtained with no apparent damage to the environment and no pollution (CO_2 emissions are low). Decreasing fossil fuel resources (oil, natural gas and coal) and global warming have led to the conclusion that human energy future belongs to the renewable energies. These are: wind energy, solar energy, thermal energy, biomass, hydroenergy. Of these, hydroelectric energy is currently the cheapest form of green energy. At the European level, the interest in increased production of energy from renewable resources occurs for more than 10 years, when it was approved by the European Parliament Directive 2001/77/EC establishing a framework for integrating the domestic mains electricity produced from renewable energy sources. Directive 2001/77/EC was the starting point that allowed Member States to build a local market of energy from renewable resources and a common European market to facilitate trade in "green energy", based on certificates of origin. This is the EU first ferm action to reduce gas emissions with greenhouse effects, thus ratifying the Kyoto Protocol. Our country has adapted its domestic legislation on this issue since 2003, and a market for green certificates was formed by HG no.1892/2004 next year. Following the consolidation of the European market of the green energy and environmental protection, the European Council adopted Directive 28 in 2009 (2009/28/EC). This Directive establishes direct and indirect instruments to achieve the objectives so that each member country shall reach a share of renewable energy on average of 20% of the total consumption of energy in 2020. Romania, as a member state of the European Union and according to its commitments, has set the target of 33% for 2010, 35% for 2015 and 38% for 2020 representing the RES-E share of the domestic electricity consumption . Of laws, government decisions and plans that concern directly the development of energy production from renewable sources (RES-E) there stand GEO no.88/2011 and no.220/2008 law and the decision-making institution in the heightened energy is ANRE (National Regulatory Authority for Energy). In Romania, the state does not finance renewable energy market (E-RES), the costs are transferred to the consumer. According to the data published by ANRE in the report of 2010, there are 65 licensed manufacturers in renewable energy, including 32 in hydro, 28 in the wind energy, 3 in biomass and one in photovoltaic energy, with an installed capacity of 520.4 MW. These entities have produced 20,264 TWh, which means 35.24% of the total gross electricity consumption of Romania, with 2.24% more than the 33% rate assumed by Romania for 2010. In 2010, following the production of energy from renewable sources one avoided the annual emission of 250,344 tonnes of CO_2, double in comparison with the previous year. In accordance with Article 6 paragraph 2 of Law nr.220/2008, modified, renewable energy producers receive from the Transmission System Operator a number of green certificates, confirming the production of 1 MWh of electricity from renewable sources. The certificate can be sold separately from the amount of electricity that it represents on OPCOM market. The trading value of green certificates is between 27Euro/certificate and 55 Euro/certificate. In 2010, the producers of RES-E revenues obtained from the sale of CV worth 37.213 million euro to support RES-E, which has led to an increase in electricity prices to final consumers with 0.841 Euro / MWh (3.552 lei / MWh). According to ANRE and Law no.220/2008 for a new hydropower plant with power less than 10 MW put into operation after 2004 for 1 MWh 3 green certificates are issued, the validity duration being of 15 years.

4. THE MHPS IN THE UPPER BASIN OF ARGES

In the current development, since 2011 on rivers in the Fagaras Mountains, southern slope, upstream Vidraru, one began the exploitation of the existing hydroenergetic potential by building several micro hydropower plants (MHPs).

4.1 MHPs - theoretical data

One considers the MHPs the hydropower plants with installed power up to 10 MW. They are located on the river, some of its water is diverted through a pipe to a turbine.

The following advantages:

- ✓ reduced costs and execution time;
- ✓ does not require qualified employees;
- ✓ require low-voltage distribution networks;
- ✓ have a long period of use;
- ✓ are flexible as regards the flow.

The main environmental issues for MHPs are:

- ✓ environmental impact of diverted water flow and the need to maintain a sufficient flow through natural riverbed;
- ✓ negative visual impact of water captation, dam (or dike) and plant building;
- ✓ any damage of fish and other organisms that pass through turbines with water
- ✓ default blocking of water flow and migration of aquatic fauna;
- ✓ impact during construction when one may need temporary dams; there is also a risk of sediment disturbance on the river bed and / or storage of construction materials in water
- ✓ scale schemes that do not involve water accumulation behind the dam have a much smaller impact on the environment;

To the scheme of harnessing of Arges river that has been highlighted in the previous pages, by these projects one adds a total of 10 MHPs (5 MHPs - Capra River, River Buda - 4 MHCs and 1 per Otic), totaling an installed capacity of 14.7 MW. Thus, the entire hydotechnical complex Arges (new and old) has a total installed capacity of 431.7 MW. They are located in Fagaras Mountains, at altitudes between 900 m and 1,600 m. One can take into account 2 harnessings, the hydroenergetic harnessing Capra and Buda-Otic. The hydroenergetic scheme is of derivation type, with medium and large chute, and the purpose is only energetical. In the minor bed there is placed a pinch and the water flows are transported gravitationally through steel pipes to turbines. On the water flows there are ensured the servitude flows determined by specific studies by INHGA.

4.2. Hydroenergetic harnessing of Capra

Capra River has its origin on the southern slope of the Fagaras Mountains at 2,000 m altidudine and it is one of the main rivers tributary to Lake Vidraru. The total reception area of the hydrographical basin is of 59 sqkm and a total length of 15 km. The investment project proposes to achieve a total of five plants with a total installed power of 6.04 MW. The total length of pipelines is about of 13 km and its diameter increases upstream (273 mm) to downstream (1219 mm).

Table 2. The characteristics of the hydroenergetic harnessing of Capra

Crt. No.	Denomination of the power plant	Altitude (mdM)		Waterfall (m)		Adduction		Installed power (MW)
		Captation	Power plant	Hb	Hn	L (m)	D (mm)	
1	H1	1682	1538	144	137	520	273	0.117
2	H2	1529	1251	278	269	3150	711	1.466
3	H3	1252.5	1100	152.5	144	3900	914	1.359
4	H4	1103.5	991	112.5	106.6	3500	1219	1.788
5	H5	988	924	64	59	1900	1219	1.31

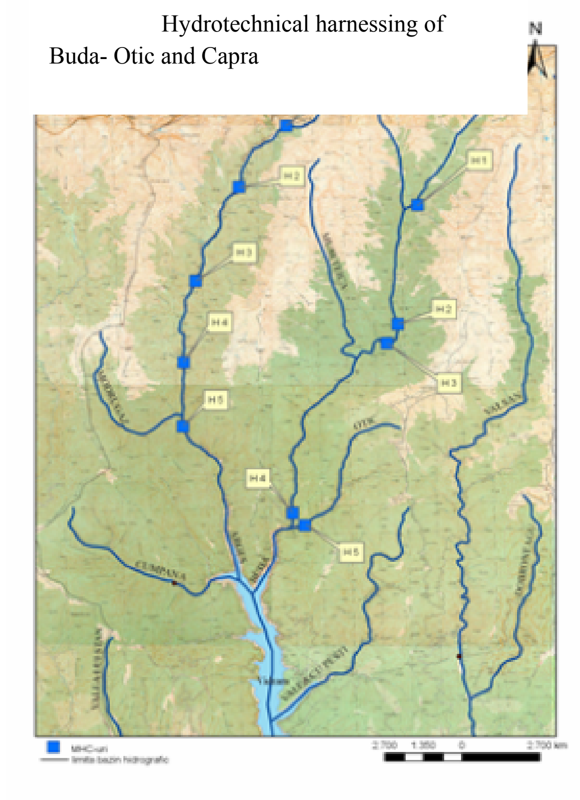

Fig. 6 Scheme of harnessing of MHPs

4.3. Hydroenergetic harnessing of Buda-Otic

Buda River is also part of Vidraru, it is a left tributary stream and it is considered to be with Capra one of the rivers. The hydrographical basin has an area of 101 square kilometers, a length of 19 km and 3 major tributary streams, including Otic River. For this harnessing, the investment plan aimed at building 5 hydropower plants, 4 on Buda and 1 on Otic. The installed power on the entire chain is of 8.22 MW.

Table 3. The characteristics of the hydroenergetic harnessing of Buda-Otic

Crt. No.	Denomination of the power plant	Altitude (mdM)		Waterfall (m)		Adduction		Installed power (MW)
		Captation	Hb	L (m)	(MW)	L (m)	D (mm)	
1	H1	1380	1270	110	95.94	2750	700	0.556
2	H2	1270	1150	120	105.15	3757	900	0.98
3	H3	1150	1040	110	95.26	3730	900	0.953
4	H4	1040	875	165	150.71	6700	1600	5.185
5	H5	1040	875	165	149.13	2100	550	0.551

The work began in the summer of 2011 have brought up a number of concerns about the impact on the environment. Environmentalists believe that there have been abuses in execution, being especially affected the riverbed and the fish fauna and the investors claim to have observed the legislation. The river beds in this region are part of the protected area Natura 2000. Within the protection area Fagaras , the minimal prohibitions included the following:

• do not work on the banks of the water except in the case of landslides
• do not build anything in the minor bed of rivers
• do not drive with any kind of vehicle in bed and on the shores of rivers
• do to make interventions on moist habitats –drainages.

Operating rules generally prohibit anything that can cause pollution, disturbance of the species and damage of the ecosystem. Investors have filed the necessary documents since 2009 to obtain both a water management notification, and a notification on the environmental management.

These were issued, but with a number of conditions that they committed that they would comply. The documents say that:

- the route of the pipeline "is approximately parallel to the bed "
- "it is forbidden to alter or to reduce the flow section "
- it is forbidden " the degradation of the riverbed and of the banks ".
- " Work is prohibited during the migration and reproduction of fish ".


Fig. 7 Figure MHPs Capra (Figure Sura Irregular works of harnessing of Fagaras MHPs)

In the autumn of the year 2011, following numerous complaints made by numerous NGOs, the Ministry of Environment and Forests ordered to cease work in order to clarify the issues.

Dilemmas

The Romanian society is called upon to answer the following questions:

1. Which is the limit between economic and environmental interests?
2. How can we afford to intervene in nature and what are the costs?

During the building of the MHPs, one works on riverbeds and on their banks, which stresses the local flora and fauna. After the execution, flow is significantly reduced at the free flow of rivers.

A variant proposed as a debate topic for the harmonization of the two interests is to amend the law in accepting flows of variable servitude, calculated according to the phases of treatment and temporary needs of flora and fauna.

REFERENCES

Bacanu I., (1963) *Physical and geographical aspects of Arges Valley,* Natura (Nature), no. 6, Bucharest

Barco A., Mihailescu A. (1973) *The Upper Valley of the Argeş River),* Studii si cercetari stiintifice (Scientific Studies and Researches), Seria geologie-geografie (Geology-Geography series), Bacau

Constantinescu M. (1990*) Hydraulic structures in Romania,* Publishing House Hidroconstructia, Bucharest

***(1983), *Romanian Geography, vol. 1, Physical Geography*, Publishing House Academiei Române

*** (1971*), Rivers of Romania (hydrological monography),* IMH, Bucharest

*** (1992), *The Atlas of Water Cadastre in Romania*, Bucharest

Valentin M. Ionescu, Ioan Gherghes Study: *Policies in electricity from renewable resources, environmental risks and risks on sustainable development*

Bogdan Olariu Article "*MHPs in Romania - eco energy or environmental disaster?"*

http://www.hydrop.pub.ro Hidroenergetica

http://www.anre.ro Renewable Reports / *Report ANRE 2010*