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ENVIRONMENTAL IMPACT AND BENEFIT FROM HYDRO ENERGY: BULGARIAN CASE

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Hydro power is one of the three main energy sources in Bulgaria. Its share shows a decreasing trend in the last decades: about 47% in 1944, 32% in 1965, 11% in 1980, 5% in 1985, 6% in 1988 and later [1,2]. That is why in Bulgarian Case Study (BCS) within DECADES Inter-Agency Project framework [3] a detailed analysis of Bulgarian hydro system is included. The substantial economic, technical and environmental features of the hydro energy facilities in the country in the past and present as well as their environmental characteristics are described in a complete and precise way.

The hydro energy has few considerable advantages in comparison with other energy sources: a renewable energy source - water, is used for electricity generation; generally, the related environmental pollution is not significant; the main facilities - hydro power plants (HPP), are fast activated and stopped (few minutes are necessary to begin or stop work), they have high coefficient of efficiency (in order of 70% and more) and can produce energy with variable quantity of water; they produce mainly the most valuable pick electricity. In respect to the economic advantages, as a rule the hydro energy costs are less than these for the other energy sources.

The hydro energy system in Bulgaria has been well developed in the past years (50 power plants have worked in 1939) and many facilities still work. The present hydro energy system has been constructed mainly in the period 1950 - 1965 (44 HPPs, 22 large and 1800 small reservoirs). The currently utilised hydropower potential, only 33% of the estimated technical potential of Bulgaria, includes 87 HPP operating in 1991. Now only one hydro energy complex is almost completed - the pumped storage system "Chaira".

The environmental aspects analysis of the main energy sources in Bulgaria based on the scheme specially developed for this purpose is realised in BCS for the thermal, nuclear and hydro energy chains correspondingly. This scheme is based on division of the main types of environmental impact - emissions into air, emissions into water, land requirements, wastes, etc. - into specific for each energy chain categories. It helps for better presentation of the environmental characteristics included in the CSDB. On the other hand, such a scheme makes easier the comparative assessment of energy generation options from environmental point of view. The scheme has the following main features:

it is constructed on the complex principle - it considers all energy chain; the specific categories are ordered level by level; when it is necessary the categories are divided into more detailed sub-categories; the environmental impact is estimated by four rates: 0 - no impact, 1 - weak impact, 2 - considerable impact, 3 - strong impact. In this way the scheme combines both synthesising and analysing approaches. Its concrete realisation for the main energy chains in Bulgaria provides an example of its practical application: for instance, the category of "Land requirements" (which presents in the three schemes) is of the least rate for nuclear energy and approximately of the same order for the thermal and hydro energy; regarding the emissions into air and water - they are the most considerable for the thermal energy; the most hydrological changes are related to the hydro energy, etc. Even in its preliminary and subjective mode the scheme permits to do comparâtive assessments so it is an useful tool for achievement the Study's goals as well as for other similar purposes.

In the case of case of hydro energy the main types of environmental impact related to the HPPs' operation can be presented in 7 specific categories: land requirements, changes in the landscape, hydrological changes, microclimatic changes, geodynamic changes, technogeneous risk and creation of new ecosystems. In order to present all levels of the hydro energy chain these categories could be divided in more detailed characteristics correspondingly:

1. Land requirements:
    1.1 Hydro power plant itself
    1.2 Related facilities (reservoirs, channels, etc.)
2. Changes in the landscape:
    2.1 Earthwork during construction period
    2.2 Recultivation during operation
3. Hydrological changes:
    3.1 Disturbance in the river's run-off
        3.1.1 In the river system itself
        3.1.2 Exchange with other river systems
    3.2 Changes in the sediment regime (hydrogeological changes)
    3.3 Changes in the water composition (hydrochemical changes)
4. Microclimatic changes:
    4.1 Changes in the climate factors (surface and circulation)
    4.2 Changes in the climatic elements (temperature,evaporation, wind, etc.)
5. Geodynamic changes:
    5.1 Changes on the facility's own territory (including the underground water)
    5.2 Changes on the surrounding territories
6. Technogenious risk
7. Generation of new ecosystems

The environmental impact of hydro energy sources for electricity generation is qualified by the developed scheme in Table 1.

Table 1: Schematic description of the environmental impact from hydro energy

Type of power plant	1		2		3			4		5		6	7
	1.1	1.2	2.1	2.2	3.1	3.2	3.3	4.1	4.2	5.1	5.2		
I.1	1	0	1	1	1	0	1	1	0	0	0	1	0
I.2	1	2	2	2	2	1	1	1-2	1	0	1	1-2	1
II.	1	2	2	2	2	2	2	1-2	1-2	2	1	1-2	2
III.	1	3	3	3	3	3	3	2-3	2-3	3	1-2	3	2

Legend: I.1 - Run-off-river without equalizer power plant
I.2- Run-off-river with equaliser power plant
II. - Pumped storage power plant
III. - Storage power plant

It can be concluded from the table that the environmental impact of the run-off-river HPP is weak to considerable (in the case of equalizers operation); the pumped storage HPP has considerable impact while the storage HPP has mostly strong impact. The number of the fourth types of HPP in Bulgaria is 40, 19, 1 and 27 correspondingly. In summary it could be estimated that the hydro energy system in the country tends to cause considerable environmental impact. It have to be considered here the combined utilisation of the hydro energy facilities - for electricity generation, irrigation and water supply, so the related environmental impact is very complex . Quantitative assessment of this impact could be obtained by entering of concrete values for the environmental characteristics presented in the above scheme in an appropriate model. In combination with the corresponding economic and technical parameters they can serve as input data for an integrative model in order to make complex assessment of the hydro energy chain as well as comparative assessment with other energy chains. The Country Specific Data Base (CSDB) is being designed in the Case Study framework so that to have all these data together. Bulgarian CSDB can be used as input for models analysing the energy system development.

It has to be pointed out, however, an another consideration of the environmental impact due to the hydro energy: relation with climate variations and change [4]. Most of the above mentioned categories for assessment of this impact relate to climate forcing factors: emissions into air - with the composition of atmosphere; landscape changes - with the earth surface; hydrological changes - with the atmospheric circulation processes. A comparison of these categories for the thermal, nuclear and hydro energy is made in Table 2. Such a comparison shows that hydro energy has considerable impact on the landscape (especially in the case of large-scale hydro-facilities) and the hydrological regime in the surrounding area. The nuclear energy has almost no impact in this sense while the thermal energy has considerable impact mostly by changes in the atmospheric composition. Relatively, the hydro energy could cause impact on climate factors comparable with that caused by thermal energy. So, more precise and quantitative assessments are necessary for such comparison.

Table 2: Impact on climate factors from different energy sources/chains

Energy source	Rate of the impact		
	Emissions into air	Landscape changes	Hydrological changes
Thermal	1 - 2 - 3	1 - 2	0 - 1
Nuclear	0 - 1	0 - 1	1 - 2
Hydro	0	1 - 2 - 3	1 - 2 - 3

One approach for such assessment is to use the technique of expertise in balls [5]. Its main idea is to compare n objects (in our case - nuclear, thermo and hydro PPs) by m experts on x_j categories for the parameter y: the less environmental impact. Quantitative expression of this can be obtained by minimising of the following equation:

$$\sum_{j=1}^{n}(y_j - \sum_{l=1}^{p} b_l x_j^{(l)})^2 ,$$

where i = 1, ... p is the number of linear equations (groups of the expert's estimations) and j = 1, ... n. This approach is being realised now on the concrete data for Bulgarian PPs.

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