Green Energy to Support Livability: A Case Study Of Energy Shift to the Small Hydro-Systems in Serbia

1. Serbia Today

In Serbia today, the generation and use of energy is taking a major toll on the natural and built environment. Extremely inefficient use of natural resources and electrical energy, dependence on imported energy, especially during the winter heating season, major losses in energy transport, low energy efficiency in industry and housing sector – these all are the reasons for the high power consumption. Total consumption of electrical energy in Serbia in 2010 was 28.051 GWh (Electric Power Industry of Serbia, 2010), and it is increasing every year. According to the forecast of Electric power industry of Serbia, total electrical energy consumption will reach 35.480 GWh by 2015. (Electric Power Industry of Serbia, 2011)

Serbia relies on energy production mainly obtained from coal – about 62% of all energy production is coal-based. Coal is primary extracted by surface mining, which, combined with its burning, has devastating effects on natural environment. The energy sector is the main pollutant in Serbia, and „existing energy sector releases into the atmosphere more than 44 million tonnes of carbon dioxide and over 300.000 tonnes of sulphur dioxide per year" (Pucar & Neković-Riznić, 2009) Use of oil and natural gas are currently much less represented, and together they participate with only 4% of total energy production.

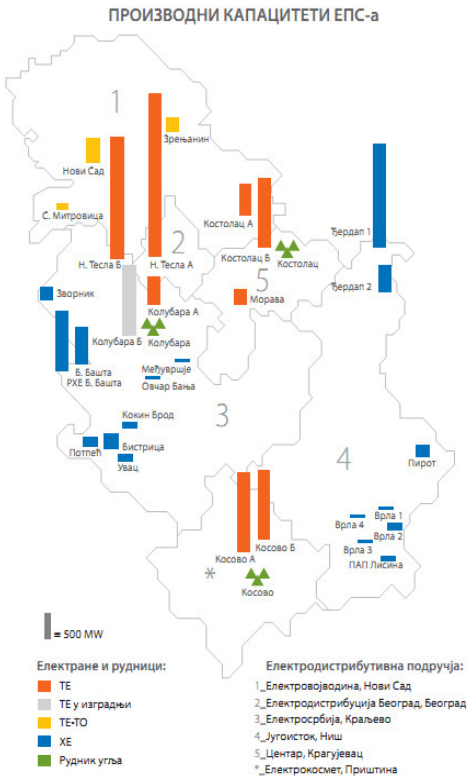

Figure 1 - Sources of energy in Serbia – blue bars represent hydropower plants (Source: Electric Power Industry of Serbia. (2010). Tehnički godišnjak 2010. Electric Power Industry of Serbia)

The second largest source of energy in Serbia is hydropower. Thirty-four percent of all energy comes from hydropower. Although the process of generating energy in hydropower

plants is considered "green", construction of power plants and area necessary for their reservoirs can, depending on the plant size, have major effect on the natural and built environment – i.e. changing the natural landscape by submersion of extensive areas upstream of the dam, altering the microclimate in the region, activating landslides, degrading the water quality in the reservoirs, relocating of people living in the area inundated by the reservoirs, flooding the areas of natural or cultural heritage sites, etc. Serbia has extensive experience with the large hydro systems and there is a general awareness of the negative effects these systems generate on their immediate surroundings.

It is estimated that the total usable hydropower potential of Serbia is approximately 17,000 GWh (Ministry of Mining and Enegry of the Republic of Serbia, 2004). Serbia utilizes 14 large hydroelectric power stations with capacity over 10 MW (Ministry of Infrastructure and Energy, 2007, 2009) and about 30 small hydro plants with total capacity of 35 MW (Office of the Vicepresident for the EU Integration, 2009), and is, therefore, using around 10.000 GWh/yr of its estimated potential. (Ministry of Infrastructure and Energy, 2007, 2009) According to the calculations there is the potential for another 7.000 GWh/yr, of which 1.800 GWh/yr could be produced from small hydro power plants. (Ministry of Mining and Enegry of the Republic of Serbia, 2004) Based on the available data, existing planning documents have identified over 850 potential sites for the construction of small hydro plants.

Due to unfavourable political and economic situation in the country in the previous two decades, development of infrastructure and therefore building of hydropower plants has been stalled, but in the last couple of years the issue has been reopened. "However, major problems are expected because the rivers planned for the utilization of hydro power are not protected by the relevant regional plans or the appropriate water management master plans of river basins or parts of basins, resulting in unplanned construction in the river valleys that hampered the terms of using some rivers attractive for energy: middle part of River Drina, Lim, Ibar, etc." (Ministry of Infrastructure and Energy, 2007, 2009)

Based on the national plans on Green Energy in the Republic of Serbia and Protocol of cooperation between the Republic of Serbia and the Republic of Italy signed in 2009, it is planned that the "Electric power industry of Serbia", public enterprise in charge of meeting all the electric power requirements in the country and the largest emitter of GHG in Serbia, will carry out a construction of series of small hydropower plants on the river Ibar. This is the first in a series of planned projects.

2. Energy, Spatial and Sustainable Development in Serbia

Planning of energy facilities in Serbia, including small hydropower plants, is regulated by several national institutions and a wide legal framework, which could roughly be divided into three categories – energy sector, sustainable development and spatial planning. Furthermore, development strategies in Serbia are constrained by its foreign affairs policy.

Serbia, Kyoto, European Union…

Serbia joined the South-East Europe regional energy market by signing the Treaty establishing the Energy Community in 2005. By signing the Treaty Serbia also committed itself to increasing the usage of renewable energy resources in its overall energy production. Considering its ambitions to become a regional leader in sustainable and green energy production, it is necessary to increase its energy capacities, which will also contribute to decreasing its dependence on imported energy and to reducing greenhouse gas emissions. Increase of this capacity can be partly achieved by building sustainable sources such as small hydropower stations, and the Ibar River has been identified as one of the potential sites.

In 2007, Serbia also signed and rectified Kyoto protocol. Although Serbia, being a developing country, is not committed to the quantitative reduction of collective greenhouse gas emissions, by signing this protocol, it has gained the opportunity to reduce these emissions through Clean Development Mechanism, through which developed countries (Annex 1) can invest in Serbian projects with the aim of reduction of the emission of greenhouse gases on its territory.

Finally, a significant factor in Serbian state policy is its tendency and priority to become a member state of EU. At the end of 2009, Serbia officially applied for EU membership, and by signing the Stabilisation and Association Agreement, Serbia committed to harmonizing its laws with those of EU which, among others, include laws on sustainable development and energy efficiency.

National strategy on Energy Development in Serbia

The most important national institutions in charge of defining and implementing energy policy in Serbia are the Ministry of Infrastructure and Energy, National Energy Efficiency Agency and the Energy Agency of the Republic of Serbia. The National energy law defines Serbian energy policy, measures, activities and long-term aims, devoting a special section to environmental protection. This law has following three main instruments of implementation: The Strategy of Energy Development of Serbia by 2015, Strategy Implementation Program and Energy Survey. In accordance with the Strategy of Energy Development adopted in 2005, the main priorities of the Serbian energy sector were defined and identified as:

- Continuity of usage, modernization, revitalization and improvement of the existing energy sources;
- Rational use of resources and increase energy efficiency;
- Careful usage of new and renewable energy resources, including the remaining hydropower potential; Among other things the emphasis is put on the construction of small hydropower plants;

This strategy also envisions the incentives for investment in the buildings of energy infrastructure which use renewable energy resources.

National strategy on Sustainable Development in Serbia

Sustainable development is an important factor in the planning of small hydropower stations as stated in the National strategy for Sustainable Development adopted in 2008. This Strategy has been based on the widely accepted principles defined by The Johannesburg Declaration on Sustainable Development, The UN Millennium Development Goals and the EU Sustainable Development Strategy (EU SDS). The Strategy identifies three main areas of sustainable development as – ecological, social and economic sustainability. The leading priorities of this Strategy are:

- EU membership;
- The development of the competitive market economy and balanced economic growth;
- Increasing human resources development and creating employment opportunities;
- Development of infrastructure and balanced regional growth;
- Environmental protection and improvement, and rational use of natural resources.

Moreover, this Strategy defines main goals of sustainable development of energy sector, which, among others, encourage the usage of renewable energy resources.

Spatial Development Plan of Serbia

The national institutions responsible for spatial planning are the Ministry of Environment, Mining and Spatial Planning and the National Agency for Spatial Planning. These institutions are responsible for defining the content, method and procedure of planning documents, which, among others, include the projects for small hydropower plants. In 2010, they developed the Spatial Development Plan of Serbia for the period 2010-2020 as the key national document. Goals of this document are:

- Balanced regional development;
- Regional competiveness;
- Sustainable use of natural resources and protection and improvement of environment;
- Protection and sustainable usage of natural and cultural heritage;
- Spatial and functional integration in the environment.

This Plan is based on previously mentioned Strategies as well as other documents and legislations, and provides the foundation for every regional and local plan and program.

While the trend of using coal as the primary source of energy in Serbia is expected to continue, gradual transition towards renewable energy sources is expected. Recently adopted national development documents on energy and spatial development (Spatial Development Plan of Serbia 2020, Energy Development Strategy and Sustainable Development in Serbia) have placed the renewable resources and production of Green Energy among the national priorities for the next twenty years. Thus, biomass, wind and solar power plants, as well as construction of a number of additional hydroelectric dams are expected to take substantial share in energy production. Unlike other countries in the region (i.e. Bulgaria, Hungary, Croatia, Slovenia etc.), fifteen years ago Serbia placed moratorium on using nuclear power which is still in effect.

In accordance with the national plans on Green Energy in the Republic of Serbia and interest expressed by both Serbian and Italian party in developing strategic collaboration in the energy sector, it is planned that the ”Electric power industry of Serbia” starts the construction of system of small hydropower plants on the river Ibar, as the first in a series of planned projects.

In weighing up large versus small hydro systems, the decision has been made to give priority to the small system option. This decision was based on a multi-factorial assessment, including factors of heritage preservation, environmental impacts, urban development, etc.

Figure 2 - Location of the River Ibar in Serbia (Source: Own work, using map from Wikimedia Commons)

3. Ibar Region

Ibar river is rising in the Hajla mountain in Montenegro from where it flows east, mostly through canyons with only a couple of widenings. In its upper course, Ibar has no major tributaries and flows through several small sparsely populated villages until it reaches the dam where it forms artificial Lake Gazivode. Continuing downwards, Ibar in its middle course passes through the city of Kosovska Mitrovica where it sharply turns north and flows by mineral and ore rich slopes of mountain Kopaonik (national park).

In the lower course, Ibar enters the municipality of Raška. It is in this section of its course that the river receives its major tributaries, passes through one of the most densely populated parts of the country, flows through 40km long and 550m deep Ibar gorge finally reaching the city of Kraljevo where it empties into Zapadna Morava River. The lower course is popularly divided into three valleys: *Valley of history* with ruins of medieval town of Maglič – a classic example of Serbian medieval military architecture, and several monasteries – Studenica, Žiča, Gradac etc., some of which are UNESCO world heritage (Studenica); *Valley of the lilacs* known by that name because of the anecdote that King Uroš I Nemanjić as a gesture of welcome to his future bride, the French princess Helen of Anjou, ordered that all the known varieties of lilac be planted alongside the Ibar river; and *Valley of the spas* with a number of spas which are among the biggest Serbian tourist attractions. It is worth noting that boundaries between these valleys are not clear and that they overlap. The 25 km long part between Maglič and Kraljevo is also home of the popular *Joy Ride* – annual whitewater rafting event.

Figure 3 - Ibar River - railroad and highway are visible in the valley (Source: http://www.panacomp.net/montenegro?mesto=timbild%20splav%20ibrom%20i%20drina)

Figure 4 - Rafting on the Ibar River (Source: CrniBombarder, Wikimedia Commons)

Part of the lower course between the city of Raška and the city of Kraljevo is planned for the construction of series of small hydropower plants. Based on geomorphologic characteristics this part can be further divided into three parts.

The first one, upstream from the village of Biljanovac, flows through the municipality of Raška. The Ibar valley is wider in this part, with asymmetric riverbanks and an average slope of 10 degrees. This part has a total altitude difference of 26m and is moderately interesting for the construction of small hydropower plants.

In the second part, from the Biljanovac village (borderline between Raška and Kraljevo municipalities) to the Lakat site, Ibar flows more quickly and frequently turns into the rapids,

through 55km long narrow gorge only sporadically widening at some parts. River bed is on average 50m wide in this part, carved into the terrain with steep symmetric riverbanks with an approximate grade of 20-35° and total altitude difference of about 150m. This part is the most appealing for the construction of small hydropower plants.

Finally, in the third part, downstream from the Lakat site, near Mataruška banja spa, Ibar becomes slow and meandering, creating one or more backwaters on its way. It flows through wide valley, Mataruška banja spa, suburbs and the city of Kraljevo. Taking in consideration its very gentle gradient (of about 1m/km) and the vicinity of settlements, this part is not attractive for the construction of small hydropower plants.

4. Case study

Background

Based on the Spatial Development Plan of Serbia 2010-2020, Strategy of Energy Development by 2015 and National strategy for Sustainable Development, as well as the Energy Community Treaty which entered into force in 2006, the Republic of Serbia and the Republic of Italy signed the Protocol of cooperation in 2009 in which the “Electric Power Industry of Serbia” and SECI Energia S.p.A. from Italy were appointed as strategic partners for the implementation of several power generation projects. According to that agreement, the ”Electric power industry of Serbia” will undertake a construction of system of small hydropower plants on the river Ibar. The design of this system was entrusted to the Jaroslav Cerni Institute for the Development of Water Resources.

Commencing of the construction activities is expected in 2012, and total project cost is estimated at about EUR 270 million. (Ministry of Infrastructure and Energy, 2007, 2009)

Project Description

The concept for the utilization of the hydropower potential of the Ibar River between the cities of Kraljevo and Raška is determined by existing settlements and infrastructure – railroad and highway that connect northern and southern part of the country. (Jaroslav Černi Institute for the Development of Water Resources, 2010)

Figure 5 - Location of the proposed stations (Source: Kozomara, D, from Petrović, J. (2011, June 8). Sa Italijanima na Ibar i Drinu. Politika)

Proposed system consists of 10 hydropower cascades of varying height ranging from 11 to 15m. Each of the planned power stations utilizes run-of-the-river flows with pondages for water storage. Although they do dam the river, artificial lakes (reservoirs) which they create are much smaller compared to the conventional hydropower plants. Proposed dams are concrete gravity dams with wide overflow spillways controlled by Tainter gates. Non-overflow part of the dam is used for the placement of the powerhouse which accommodates two horizontal S turbines, compact turbines, and auxiliary equipment.

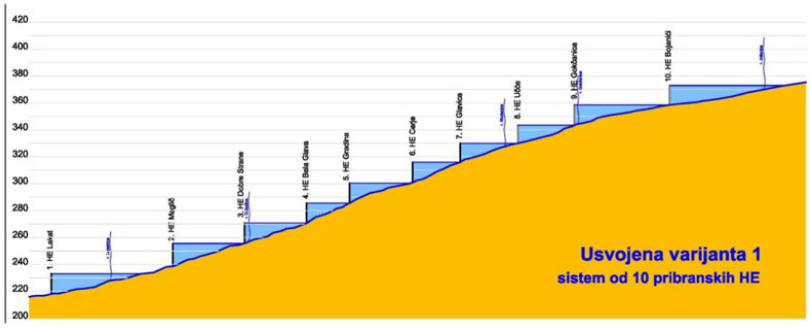

Figure 6 - Hydropower cascades - longitudinal section (Source: Jaroslav Černi Institute for the Development of Water Resources 2010, "Master Plan And Prefeasibility Study of Hydroelectric Power Plants on The Ibar River.")

Out of the available gross head of 155 m, this concept will utilize approximately 149 m, in order to avoid flooding of the lowest part of the railroad between Lakat site and Maglič site.

Installed discharge on all 10 hydropower plants is 100 m^3/s, and total power is 103.15 MW. It is expected that the system will annually output 418.6 GWh/year on average. The lowest output is expected in August and September, and the highest in the months of March and April.

Site	**Generating capacity [MW]**	**Avg. annual output [GWh/yr]**
Lakat	11	48.4
Maglič	12	50.7
Dobre strane	10.5	45
Bela glava	9.9	42.4
Gradina	10.8	45
Cerje	10.5	43.7
Glavica	9.8	40.4
Ušće	8.5	31
Gokčanica	10.3	37
Bojanići	9.7	34.5
Total	**103.15**	**418.6**

Table 1 - Generating capacity and annual output of hydropower plants on the Ibar River (Based on the data form: Jaroslav Černi Institute for the Development of Water Resources 2010, "Master Plan And Prefeasibility Study of Hydroelectric Power Plants on The Ibar River.")

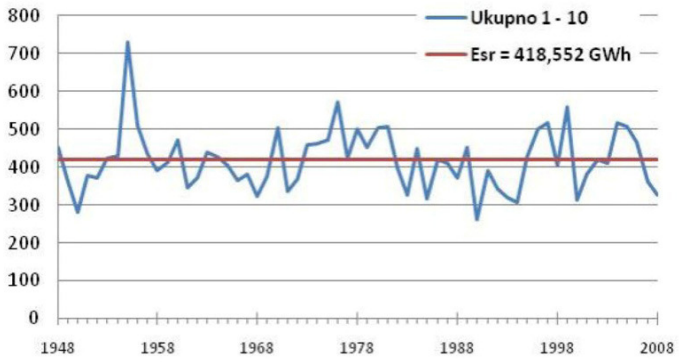

Figure 7 - Total expected annual output of hydropower plants on the River Ibar (Source: Jaroslav Černi Institute for the Development of Water Resources 2010, "Master Plan And Prefeasibility Study of Hydroelectric Power Plants on The Ibar River.")

In accordance with the Spatial Development Plan of Serbia, the most important site limitations are existing settlements. Several villages are located nearby – Bogutovac, Ušće, Biljanovac, Baljevac and Raška. This was one of the crucial factors that influenced the choice of small hydropower plants. Since the proposed power stations are run-of-the-river small hydroelectric plants, and do not require large reservoirs, dislocation of people was kept to a minimum. The immediate surroundings of the reservoirs are sparsely populated, and

agricultural land is not of high quality (Jaroslav Černi Institute for the Development of Water Resources, 2010).

Another significant site constraint is the existing highway and railroad located low in the valley along the foreshore, very close to the river. These vital routes connect northern and southern part of the country. Due to the important traffic they carry, and high price of its relocation, flooding any part of these routes, and therefore closing them for a period of time should be avoided. Proposed system keeps the railroad intact, but flooding of 5.5 km of the highway where five dams will be constructed (Maglič, Dobre strane, Bela glava, Cerje and Glavica) cannot be avoided. It is planned to build road across one of the dams (Cerje dam), thus connecting left and right sides of the river.

Finally, the active use of River Ibar for sports and recreational activities, such as rafting, was another factor that influenced the design.

Environmental Concerns and Impacts on Project

Hydroelectric power plants can slow natural river flow, reduce downstream water levels, alter water temperatures, timing of flows etc. and generally have an impact on river ecosystems.

Given the fact that the proposed hydropower plants are small, run-of-the-river type, with small reservoirs and short water retention time, they do not cause major changes in the river flow. Because of that, no major deterioration of water quality in the reservoirs, or adverse impact on existing drinking water sources downstream is expected (Jaroslav Černi Institute for the Development of Water Resources, 2010).

Furthermore, the smaller the reservoir volume, the lesser the effects on microclimate. According to the prefeasibility study, small hydropower plants have minimal impact on the microclimate in the vicinity of the reservoir. Due to the effect of evaporation, high temperature decreases in the areas near water (during the summer), and low temperature increases (in the winter).

Slowing the river flow may decrease oxygen levels in reservoirs, but when passing through the turbines and over spillways water oxygen level increases. Although final oxygen levels are hard to predict, based on the assumptions, no major problems are expected. (Jaroslav Černi Institute for the Development of Water Resources, 2010)

In order to mitigate the effects of dam construction on aquatic ecosystem, several measures are proposed, such as placement of fish diversion screens on water intakes to prevent entrance of fish into penstock, obligation of permanent discharge and guaranteed ecological flow to sustain fish and other aquatic organisms downstream, and minimizing fluctuations and maintaining sufficient water level in pondages so that the fish spawn is protected.

According to the prefeasibility study, the most widespread fish species in this part of the river are non-migratory that live and breed in fast flowing waters with rocky or gravel bottom. Another common species undertakes a relatively short upstream migration in order to spawn in the mouths of smaller tributaries. Slowing the river will have considerable negative impact on their population. In contrast, this may favour fish species living in slow-flowing and deeper waters. Considering the fact that the most common fish species in this part of the river are non-migratory species, fish ladders are not planned. Instead, it is proposed to create fish hatchery and constantly monitor state of fish stocks.

It is anticipated that this project will cause major changes in the sediment regime. Since the sediment transport depends on the flow of water, slowing the flow will affect its movement, and damming the river will prevent the passage of some particles. As a result, it is expected that the sediment will accumulate and deposit upstream from the dams (especially in the most upstream reservoir) and in the mouths of tributaries. Given the small volume of reservoirs, sediments can quickly fill them up thus affecting the operation of the power plant, while lower sediment content downstream will increase river clarity and reduce amount of

nutrients and organic material in the water. Because of that, it is necessary to constantly monitor the sediment in transport in the stream, and periodically clean the deposited sediments upstream (Jaroslav Černi Institute for the Development of Water Resources, 2010).

It should be mentioned that the environmental concerns expressed here are based on the Prefeasibility Study of Hydroelectric Power Plants on The Ibar River, and that the appropriate environmental impact assessment study is not yet conducted.

Quality Of Life and Socio-Economic Impacts

This region is economically passive. Estimated investments of EUR 270 million could contribute to the economic development of the region during the construction phase by means of hiring local population for the workforce, local industry for supplying with building materials (i.e. wood and metal industry), engaging food industry, etc., and it could also create new workplaces for the skilled workforce on maintenance jobs, system monitoring etc. when the facilities become operational. Furthermore, municipalities could generate revenue from resource rents, or compensation for the water use.

Newly created lakes also have potential for development of tourism. Given that the water level fluctuations are very low, lakeshores are stable and do not change much, meaning that the lakes can be used for water sports, recreation, picnics, fishing, or some form of ecotourism (Jaroslav Černi Institute for the Development of Water Resources, 2010). There is also a possibility of building catering and hospitality facilities, though care should be taken to minimize the impact on the environment. All of this could further contribute to the development of this region and its economy.

Figure 8 - Joy Ride on the River Ibar (Source: Aleksandar Lazović, http://www.skibus.rs/ponuda/rafting/veseli-spust)

Previously mentioned *Joy Ride* event – annual whitewater rafting on the Ibar River on homemade and improvised rafts, which starts from the medieval town of Maglič and ends in the city of Kraljevo – will suffer the most. In order to minimize this negative effect, it is proposed to divert part of the river flow on the site of the power station Lakat (which prevents the passage of rafters) thus building an artificial whitewater.

Figure 9 - Maglič fortress (Source: Own work)

This part of the river also has important historical significance. Known by the names of *Valley of history* and *Valley of the lilacs,* it is considered the birthplace of medieval Serbian state and is home to some of the most valuable Serbian monasteries from that period as well as the mediaeval town of Maglič placed atop a hill around which the Ibar River makes a curve. Special care will be taken to ensure that the newly created power plant complies with the context and preserves the identity of the Maglič town and its specific historic, architectural and ambience values. It should be noted that the exact terms for the construction of power plant near the Maglič town will be determined in cooperation with the Cultural Heritage Preservation Institute of the Republic of Serbia, and will be specified in the Spatial plan for the special purposes of system of hydropower plants on the River Ibar after the public review.

Finally, the road planned to be built across the Cerje dam will help to connect left and right sides of the river thus providing easier access to the potential tourist areas, historical sites, and the residents living on the opposite side.

5. Current developments

During the time of writing of this paper, the contract between Public enterprise ”Electric power industry of Serbia” and SECI Energia S.p.A. from Italy was signed. The financing of the project is divided in ratio 49:51 in favour of SECI Energia.

Before the construction can commence, it is necessary for detailed plans for the affected region and detailed environmental impact assessment study to be prepared. Republic Agency for Spatial Planning in cooperation with Kraljevo planning and development agency are preparing the Spatial plan for the special purposes of system of hydropower plants on the River Ibar. This plan will provide precise terms for the locations, construction and characteristics of proposed plants. As a part of this Plan, a preparation of a detailed environmental impact assessment study is crucial. Work on this study is yet to begin.

The project presented here is not in its final stage. The Jaroslav Černi Institute for the Development of Water Resources is in charge for drafting the final project for the hydropower plants. Exact locations of dams and lakes as well as the characteristics of power plants are subject to change, although no major changes are to be expected.

It is expected that the construction of the first dam will start in the year of 2012.

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