

HYDROPOWER PRESSURE ON EUROPEAN

RIVERS

THE STORY IN NUMBERS



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LIST OF ACRONYMS

IUCN	International Union for the Conservation of Nature
MW	Megawatt (installed power)
WFD	EU Water Framework Directive
WWF	World Wide Fund for Nature

EXECUTIVE SUMMARY

The hydropower sector is booming worldwide. Europe is no exception to this trend, even though most of the hydropower potential on the continent has already been harnessed. A large part of the increase is due to the development of small hydropower plants (0.1-10 MW).

This study presents the first inventory of hydropower in the whole of Europe¹, and overlays them with Europe's protected areas.

The inventory shows regional differences and highlights the regions most vulnerable to new hydropower developments. Often, these house some of Europe's most pristine and biodiversity-rich rivers.

KEY FINDINGS

Hydropower presence in European rivers is massive: The inventory reveals a total of 30,172 plants in Europe. Out of these, 21,387 already exist, 8,507 are planned to be built, and 278 are already under construction. Figure ES 1 illustrates their spatial distribution, and highlights the density of existing plants.

Most hydropower plants are small hydropower plants: The high number of hydropower plants in Europe can be explained by the dominance of small plants (Figure ES 2). Small hydropower plants come with a large ecological impact because they are numerous and disrupt river continuity, whilst contributing minimally to electricity production.

Hydropower development is happening in most regions of Europe: Hydropower plants (often small hydropower plants) are under development in all countries (Figure ES 3). However, there are strong differences of size classes and development dynamics. In Western European countries, hydropower increase is realised mostly by pumped-storage plants and the upgrade of existing hydropower plants. In Portugal, the Balkan countries, some Eastern European countries and Turkey, the number of large run-of-the-river plants increases each year. Hot spots of development of medium and large hydropower plants in Western Europe are Portugal, Switzerland and Austria. Hydropower in Norway and Scotland is growing steadily, especially for small hydropower plants and pumped storage ones. The most dynamic development can be found in the Balkan region, Turkey and some Eastern European countries. Albania and Turkey are also developing large hydropower plants.

1. The project area is comprised of all continental EU countries including Switzerland, Norway and Iceland, and stretches towards the eastern and south eastern borders of Europe including the Balkans, Belarus, Ukraine and Turkey. Overall, this mapping covers an area of 6,687,608 km² (for the sake of comparison, the largest river included in this mapping – the Danube basin – covers around 800,000 km²).

FIGURE ES 1: Distribution of recorded hydropower plants in Europe

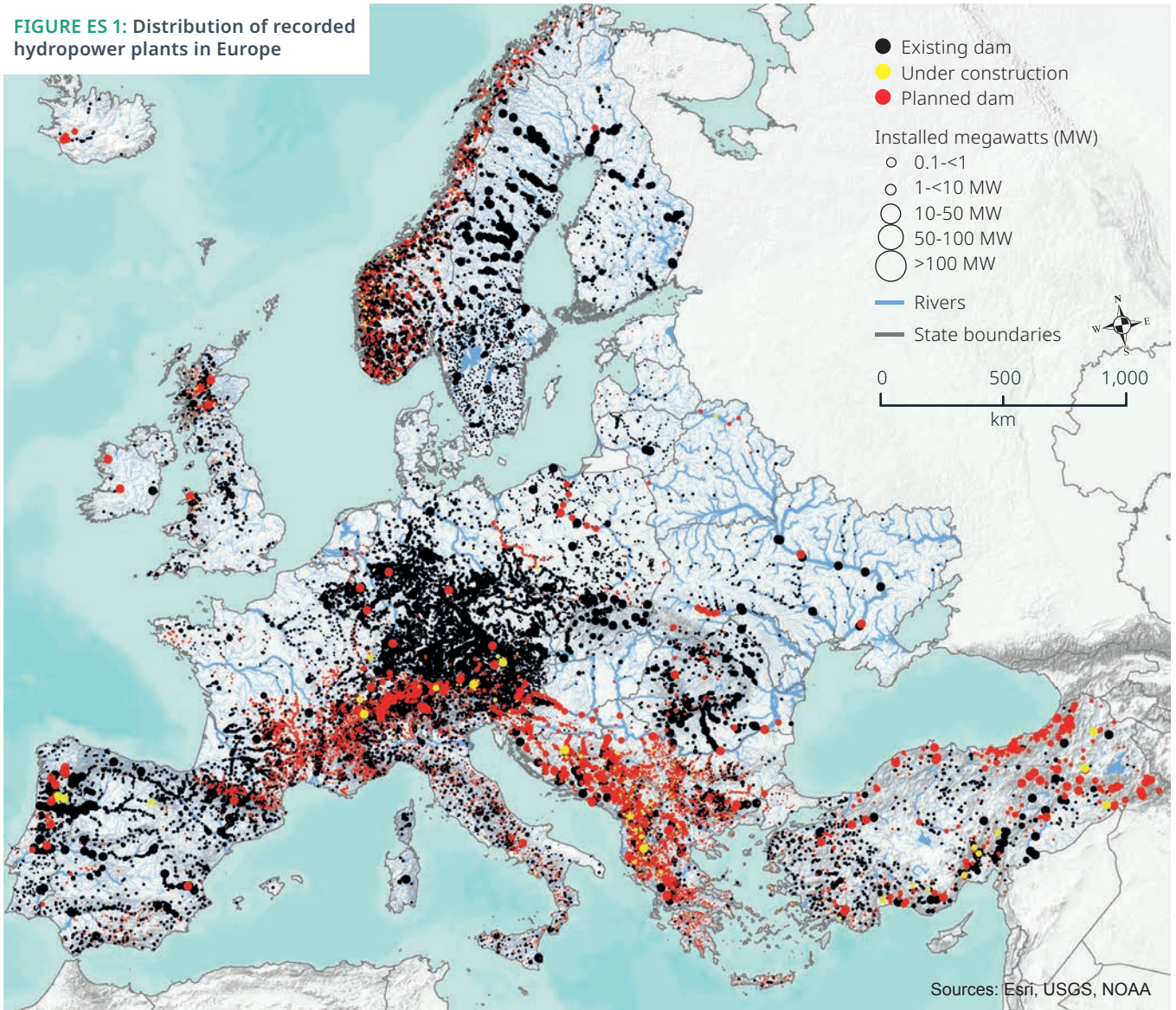
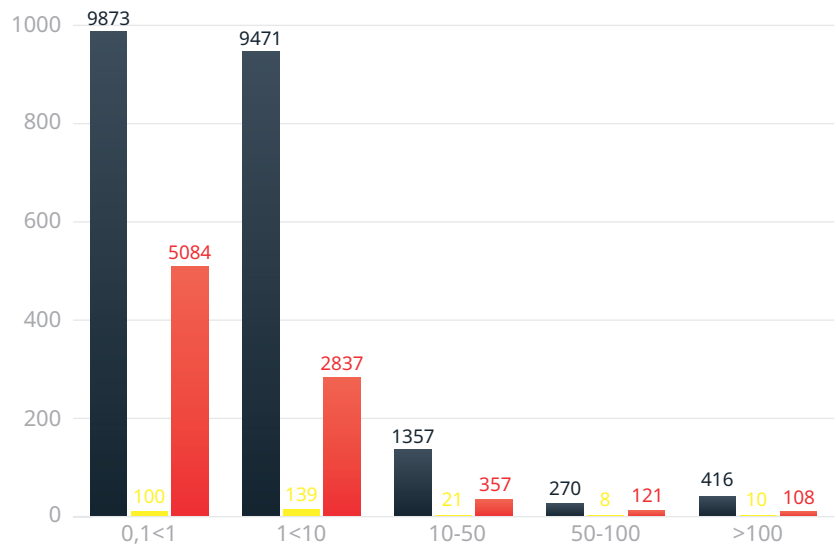


FIGURE ES 2: Distribution of all recorded hydropower plants by status and size class

- Existing
- Under construction
- Planned



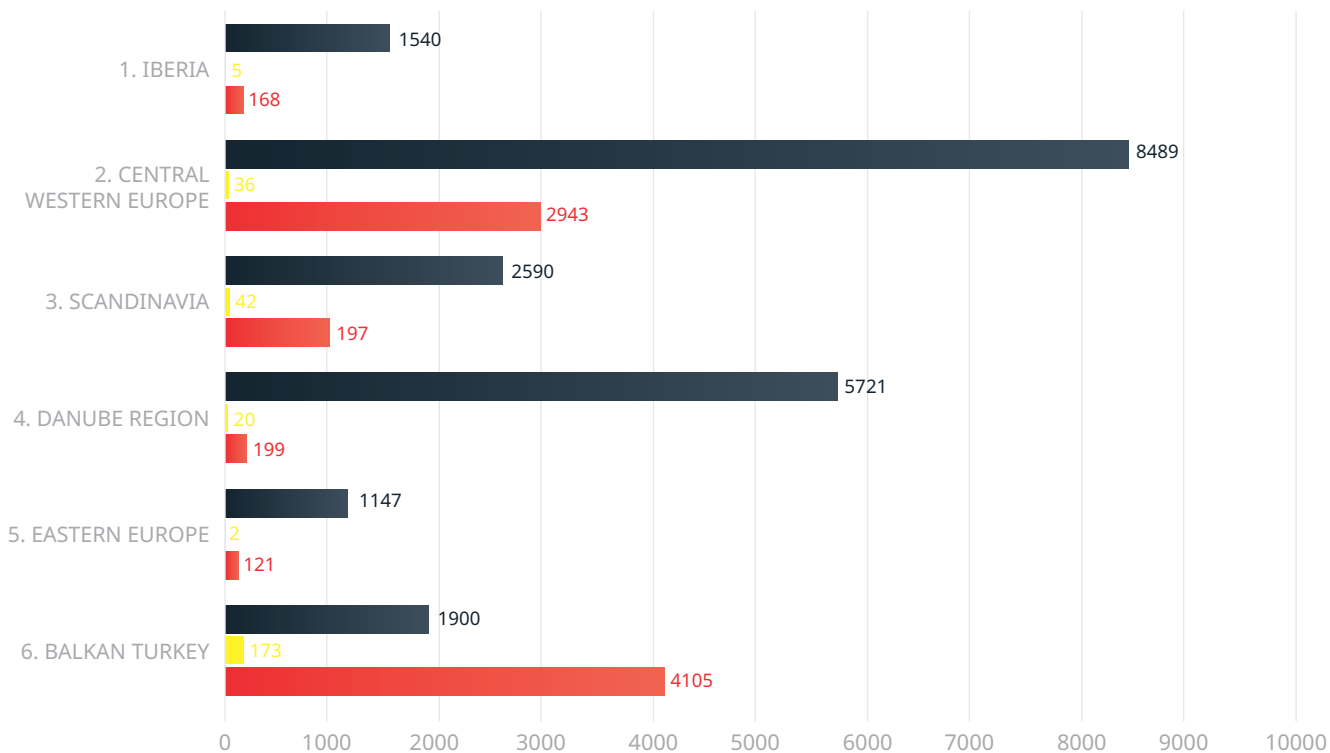


FIGURE ES 3: Distribution of hydropower plants in the different regions

- Existing
- Under construction
- Planned

Protected areas are not spared from hydropower development: 21% (6,409) of hydropower plants in Europe are located in protected areas, with 3,936 existing, 2,396 planned, and 77 currently under construction.

Figure ES 4 shows the overlay of hydropower plants with the underlying network of protected areas, split into three categories of types of protected areas. Figure ES 5 shows the number of hydropower plants in each of these categories. Currently category II, which includes Natura 2000 areas, is home to the most hydropower plants (4,739). Out of the 2,396 plants planned in protected areas, 572 are located in the highest category of protected areas, which includes national parks, World Heritage sites, Ramsar sites or biosphere reserves.

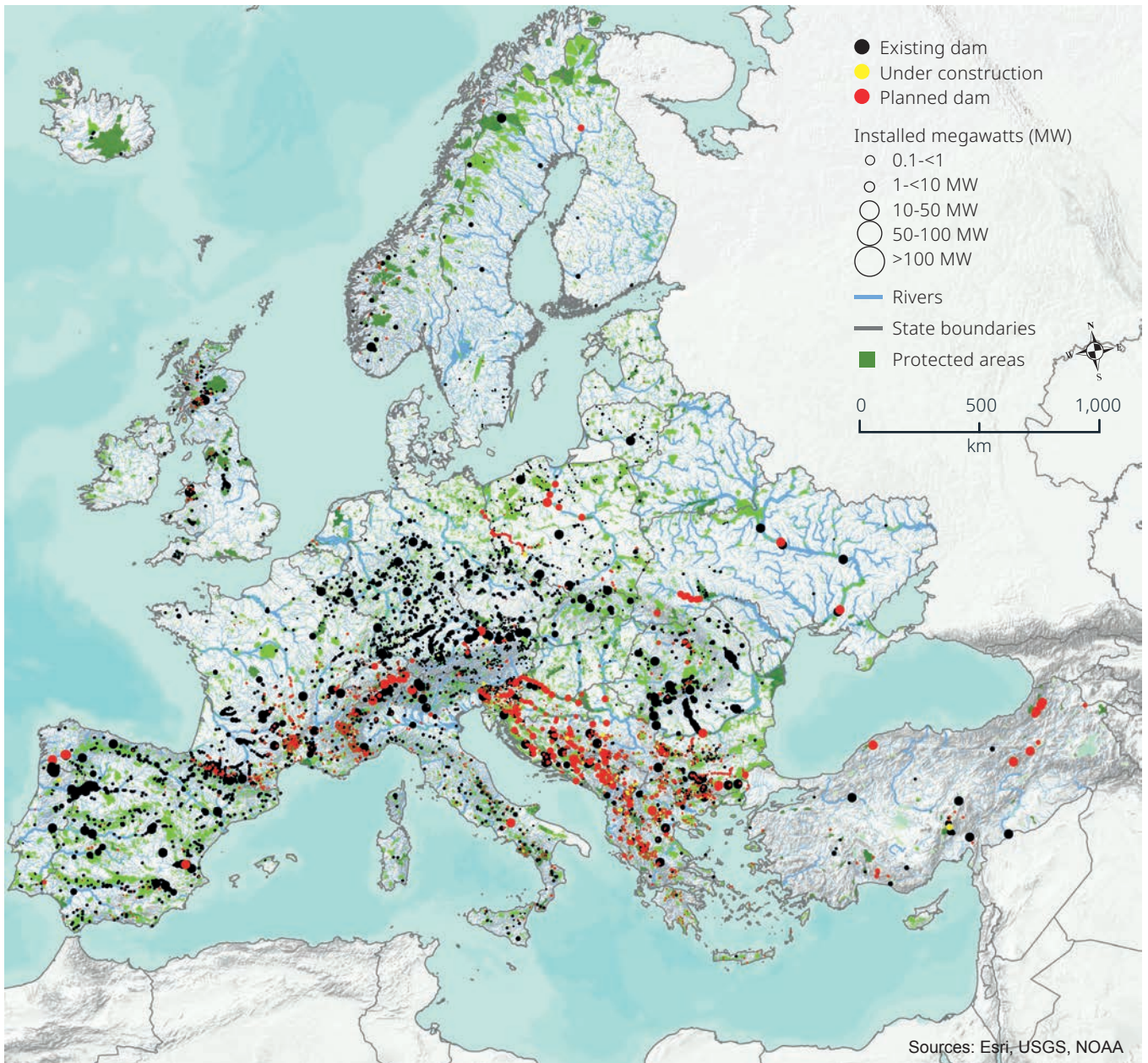


FIGURE ES 4: Hydropower plants in Europe in protected areas. The protected areas have been categorised as follows:

Category 1: National parks, Ramsar sites, World Heritage sites, biosphere reserves

Category 2: Natura 2000, Emerald areas for Eastern Europe, nature reserves

Category 3: Landscape protection

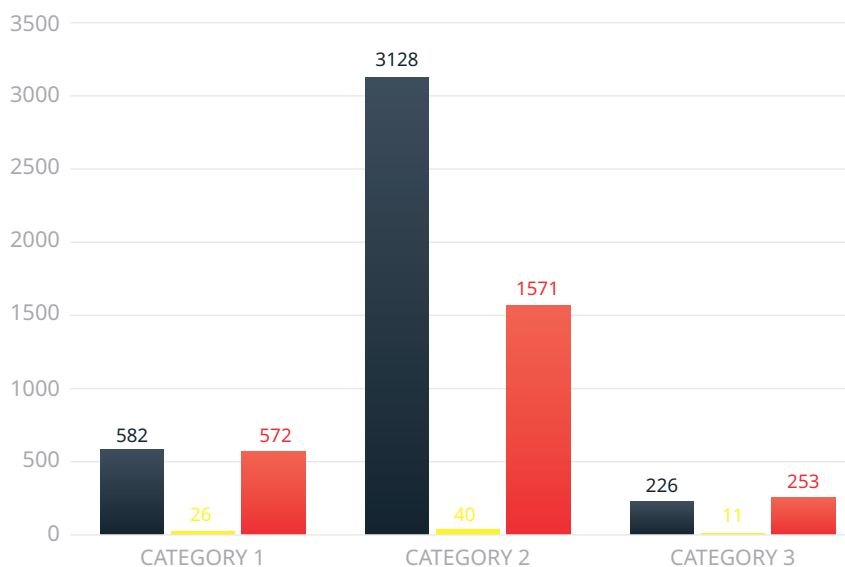
FIGURE ES 5: Hydropower plants in Europe inside of protected areas. The protected areas have been categorised as follows:

Category 1: National parks, Ramsar sites, World Heritage sites, biosphere reserves

Category 2: Natura 2000, Emerald areas for Eastern Europe, nature reserves

Category 3: Landscape protection

- Existing
- Under construction
- Planned



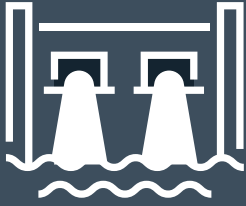
Findings discredit further hydropower development in Europe: The number of hydropower plants in Europe is already exceptionally high and their overlap with protected areas reveal a tremendous pressure on Europe's biodiversity, and for specific projects a disregard for Europe's nature protection laws. Nonetheless, projects are still being planned across Europe, some within protected areas.

The significant hydromorphological changes caused by hydropower plants are one of the main reasons why water bodies are failing to reach good ecological status under the EU Water Framework Directive. The past 10 years clearly show, for instance in the Balkans and Turkey, how quickly entire originally pristine river stretches can be degraded by being turned into impoundments. New hydropower projects in the last remaining free-flowing or intact rivers in Europe must be prevented. Planned hydropower projects, especially in protected areas, should not be allowed to move forward considering their severe impacts on Europe's biodiversity.

THE STORY IN NUMBERS:

● All of Europe ● Within the EU

Total number of recorded hydropower plants in Europe/ EU:



21,387/ 19,268
existing



278/ 122
under construction



8,507/ 5,734
planned

Country with highest intensity of hydropower*

*based on potential used, density and number of hydropower plants



Switzerland



Austria



Norway



France



Germany



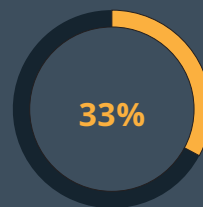
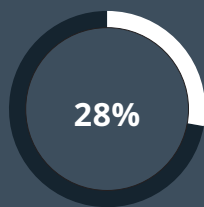
Portugal

Total amount of existing hydropower plants in protected areas in Europe/EU

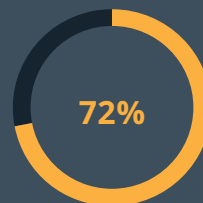
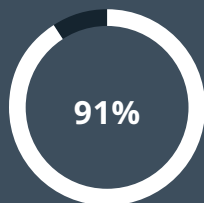


3,936 / 3,557

% of planned hydropower plants in protected areas in Europe/EU



% of small hydropower (0.1-10 MW) plants in Europe/EU



1

INTRODUCTION

Numerous reports around hydropower in Europe have been published in recent years with topics ranging from the damage done to biodiversity, to the financing of hydropower projects, to spotlighting individual communities and local activists fighting against specific projects.

Yet, despite this growing amount of analysis and attention, there was no existing comprehensive overview of the prevalence of hydropower plants in Europe, especially with regards to their location, (e.g. in protected areas), nor to their size (e.g. how much they contribute to electricity production).

Many countries have already harnessed most of their hydropower potential, like Switzerland, Norway, and Austria, and only a few countries with pristine free-flowing rivers remain. Although hydropower is considered a renewable electricity source and therefore often described as “green”, it actually comes with significant environmental impacts on free-flowing rivers.

The damaging impacts of hydropower plants on ecosystems have already been relatively well studied for large hydropower dams. These range from river fragmentation², which prevents the free movement of organisms, to severe modification of river flow and temperature regimes and to dramatic reductions in sediment transport, resulting in a loss in ecosystem services and biodiversity (Vörösmarty et al. 2010; Liermann et al. 2012).

The steady increase in small hydropower plants comes with its own unique sets of impacts. Their small size allows them to be built in more remote areas such as in high gradient alpine streams. These ecosystems typically support unique and endemic fauna and flora that have specifically adapted to thrive in these environments. (Zarfl *et al.*, 2014; Lange *et al.*, 2015). These changes to flow regimes create less selective habitats and thus reduce genetic diversity of endemic fauna, as well as makes the new habitat more accessible for non-native generalist species. By changing the community structure and genetic diversity, the whole system becomes less able to adapt to a changing world (Lange *et al.*, 2015).

These destructive effects were observed in several European rivers. In Belgium, the river Lhomme experienced a 50-59% reduction in fish biomass in the 4 years after the start up of the hydropower plant. Similarly in the Czech Republic the weirs formed migratory barriers for brown trout and grayling. In Portugal the establishment of run-of-the-river plants resulted in an accumulation of fine sediment and organic matter, and which impacted the invertebrate density in the affected river stretches (Anderson *et al.*, 2015). Studies have also shown that loss of river connectivity is likely the main reason for the decline in salmon in Europe.

The most recent Living Planet Index, published in 2018 by WWF, shows that freshwater species are the most threatened in the world, showing an 83% decline in freshwater species populations in only the past 50 years. As mentioned earlier, hydropower development, is a leading factor. Why freshwater ecosystems are not reaching good status according to the Water Framework Directive (EEA Report No.7, 2018).

2. River fragmentation is defined as the interruption of a river's natural flow by dams, inter-basin transfers or water withdrawal, and is an indicator of the degree to which rivers have been modified by human activity (UN Environment).

FRESHWATER SPECIES ARE THE MOST THREATENED IN THE WORLD, SHOWING AN 83% DECLINE IN SPECIES POPULATION IN THE PAST 50 YEARS

The EU has several strong pieces of legislation that are meant to protect, amongst others, freshwater ecosystems from the negative effects of hydropower development, and which should, if applied and enforced, have limited this expansion, particularly in protected areas. The Water Framework Directive (WFD) recognises that “water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such”. The WFD’s non-deterioration obligation prohibits any development that would negatively affect freshwater ecosystems. Therefore, hydropower dams can only be built if very specific criteria are met. All other developments are against the law. Even non-EU countries like Norway have decided to implement the WFD, and Switzerland has its own piece of national legislation meant to protect their own water ecosystems. EU accession countries like the Balkans are also required to implement the EU environmental acquis. The EU Habitats directive in Article 6.2 also states that Member States must “take appropriate measures to avoid any deterioration of habitat types and habitats of species or any significant disturbance of the species present.”

The following study is structured as follows. **Section 2** outlines the applied assessment methodology used to create a comprehensive overview of existing, planned, and hydropower plants that are under construction. **Section 3** presents the main results of this report, organised in a European overview and looking into more detail at the six regions studied in this report. The last section, **Section 4**, concludes on the situation of hydropower development across Europe and provides some policy recommendations to ensure the survival of the last free-flowing rivers in Europe.

THE EU WATER FRAMEWORK DIRECTIVE RECOGNISES THAT “WATER IS NOT A COMMERCIAL PRODUCT LIKE ANY OTHER BUT, RATHER, A HERITAGE WHICH MUST BE PROTECTED, DEFENDED AND TREATED AS SUCH”

2

METHODOLOGY AND ASSESSMENT

2.1 INVENTORY OF HYDROPOWER DAMS

The methodology for this inventory is strongly based on analysis which has already taken place in the Balkans (Schwarz 2012) and Mediterranean (Schwarz 2019) and the Balkan Eco masterplan (RiverWatch and EuroNatur 2018).

All existing, planned, and plants under construction that generate > 1 MW were included in the inventory. Smaller hydropower plants (0,1-1MW) were considered where possible – information on these though is scarcer, and because they are so numerous, it would not be feasible to include all of them within the scope of this study.

Regarding Geographic Information Systems (GIS) base data, publicly available datasets were compiled for this specific purpose. Specifically, the European river and catchment data, which was complemented by the Hydro-sheds platform of the United States Geological Survey (USGS) and WWF³ were used. Because the inventory was compiled on a European scale and beyond, the existing European and global dam databases were reviewed. Exchanges with most of the organizations and research groups was established to improve the existing data sets on dams. In this context, Global Dam Watch (GDW⁴) has to be mentioned, which collects dam and reservoir data worldwide in much higher thematic resolution. So far, only a few data platforms deal with planned dams and projects such as the GRanD⁵.

Geographical scope: The entire area studied covers several climatic zones and numerous bioregions, and is comprised of a large variety of river types and sizes. The largest rivers include the Rhine, Rhone, Po and major Iberian catchments, the Danube basin as well as Eastern rivers like the Odra and Dnepr. The Volga has not been included in this study, but has been exploited by 9 huge hydropower dams, which are distributed over two thirds of the entire river course.

Of the climatic zones and ecoregions that have been covered, the mountainous and water-rich regions are of particular interest for hydropower development. Additionally, water-rich lowland rivers are also being exploited to a large extent. To allow a better overview of the results, 6 subregions were defined (an analysis by country is included in section 3):

- 1** Iberian Peninsula (Andorra, Portugal, Spain)
- 2** Central Western European region (Belgium, France, Germany, Ireland, Italy, Luxembourg, Malta, Monaco, the Netherlands, San Marino, Switzerland, United Kingdom)
- 3** Northern European region, Scandinavia (Denmark, Finland, Iceland, Norway, Sweden)
- 4** Central Eastern Europe, Danube region (Austria, Czech Republic, Hungary, Romania, Slovakia)
- 5** Eastern European region with Baltic countries (Belarus, Estonia, Latvia, Lithuania, Moldova, Poland, Ukraine)
- 6** Balkan and Eastern Mediterranean region (Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Greece, Kosovo, Macedonia, Montenegro, Serbia, Slovenia, Turkey)

3. <https://hydrosheds.cr.usgs.gov/dataavail.php>

4. <http://globaldamwatch.org/>

5. https://www.researchgate.net/publication/266172562_Global_Reservoir_and_Dam_GranD_database

HYDROPOWER DAMS WERE COLLECTED IN THREE BASIC CATEGORIES: EXISTING, UNDER CONSTRUCTION AND PLANNED. IN THIS STUDY, PLANNED DAMS ARE THOSE CONSIDERED OFFICIALLY PLANNED, LICENCED AND POTENTIALLY DESIGNATED HYDROPOWER PLANTS

Status of plants: Hydropower dams were collected in three basic categories: existing, under construction and planned. In this study, planned dams are those considered officially planned, licenced and potentially designated hydropower plants.

The number of potential plants which are not mapped by this study can be estimated at around 10,000 hydropower plants, counting at least 500 economically feasible potential sites in the 20 largest countries. This is still a rather conservative estimate considering that Poland, for instance, indicates only 8,000 potential sites, or the EU initiative “Restore Mills” counts 48,000 old mill sites or places with existing barriers (weirs/ramps) which could potentially be turned into small hydropower plants.

Size classes: Throughout the study, hydropower plants are distinguished by five size classes based on installed power:

- 1) 0.1-<1 MW (only considered where possible)
- 2) 1-<10 MW
- 3) 10 -<50 MW
- 4) 50-<100 MW
- 5) >100 MW

Plants in size classes 1 and 2 are considered small hydropower plants, size class 3 as medium-sized hydropower plants, and plants in size classes 4 and 5 are considered as large hydropower plants.

Micro hydropower plants (<0.1 MW) are excluded from this study.

As mentioned previously, the number of hydropower plants in class 1 (0.1-<1 MW) is hard to determine as published inventories are sparse and the location of planned plants is often unknown. The numbers of stream barriers recorded by the EU AMBER project is around 100,000 obstacles. This large number makes it impossible to include all small hydropower plants in this study, so data from the AMBER project has not been included in this study. It seems that for some specific projects, approvals existed, but the plants were either never built or out of operation. However, as reactivating these small plants can have adverse effects, these were also considered in the study.

Data collection: The information collected for each plant was the name of hydropower plant, code (country plus 4 digit number), the name of the river, MW class and status (operating, under construction, planned).

The inventory aims to include and integrate data from various sources mostly validated by screening using high resolution satellite data. However, both the number of hydropower plants and the number of turbines can vary significantly. When one hydropower plant includes several turbines (including where one turbine is used for run-of-the-river mode and another one for pumped storage), often those turbines are summarised by one dot on the map and their respective capacities are aggregated. In particular, the precise distinction of size class of small hydropower plants proved difficult as countries often do not provide data for small hydropower plants in sufficient detail.

Limits of the study: This study cannot predict the specific impacts of individual dam projects. There is evidence of the damages of hydropeaking and the influence of changed hydrological regimes. These include eliminating ecologically important smaller floods occurring every 1-5 years, and channel degradation by river bed incision, which can still be measured 200 km downstream of larger rivers. Further downstream impacts of dams can only be inferred from that.

It shall also be noted that other major ongoing hydromorphological pressures with significant regional importance, such as sediment exploitation, river regulation, navigation, flood protection, water abstraction, irrigation or land-use development (agriculture, settlements, infrastructure) are not included in this inventory but add on to the hydropower pressure on European rivers, amongst the overarching environmental impacts of hydropower highlighted earlier in the report.

2.2 OVERVIEW OF PROTECTED AREAS

The inventory includes polygon layers of protected areas in GIS as well as basic information and serves only as a simple assessment layer:

- Name
- Size
- Type (Natura 2000, national park, biosphere reserve, Ramsar site, Emerald area.)

For the purpose of this study, several datasets were used such as the EU Natura 2000 data the World Database on Protected Areas, amended by current information of Ramsar and UNESCO lists, and the Emerald areas for Eastern Europe as well as national data, e.g. on national parks.

Three major classes of protected areas were defined using international datasets (Natura 2000, World Database on Protected Areas (WDPA) and Emerald areas):

- 1 National parks, Ramsar sites, World Heritage sites, biosphere reserves
- 2 Natura 2000, Emerald areas for Eastern Europe, nature reserves
- 3 Other categories of landscape protection, excluding hunting or special management categories.

The types of hydropower plants included in this inventory vary from run-of-the-river⁶ plants, water abstraction hydropower plants with residual “old” river channels, to pumped storage⁷ hydropower plants, making the comparability and impacts more complex. In addition, in the Mediterranean region reservoirs primarily serve as water storage for irrigation; as energy production is only a secondary function, many reservoirs in this region are not considered in the inventory.

6. These plants channel a portion of a river through a smaller canal. Often small hydropower plants are diversion plants.

7. Pumped-storage hydropower plants use cheap energy to pump water during the night (at a time when energy demand is low) in an upper basin, releasing it at high consuming times during the day in a lower basin or river. They also serve as a load balancing system capable of temporarily storing surplus energy in the grid.

3

RESULTS

3.1 EUROPE AS A WHOLE

In total 30,172 hydropower plants have been recorded: out of those 8,507 are planned, 278 are under construction and 21,387 are currently in operation.

There are clear regional differences regarding further hydropower development. In general the pressure of hydropower development is highest on the Balkans and Turkey. Turkey for instance has 6 large dams currently under construction (Figure 2).

The International Hydropower Association estimated hydropower plant developments in 2017 to 2,307 MW in total (IHA 2018), with half coming from pumped storage (e.g. within the Alpine arc), and another quarter from refurbishment and extension of turbines of existing dams.

Planned hydropower plants are mainly small plants (Figure 3). Regarding the geographic distribution, Central Western Europe houses most of the existing hydropower plants. It is clear that the Balkan region and Turkey will be most affected by future development (Figure 4).

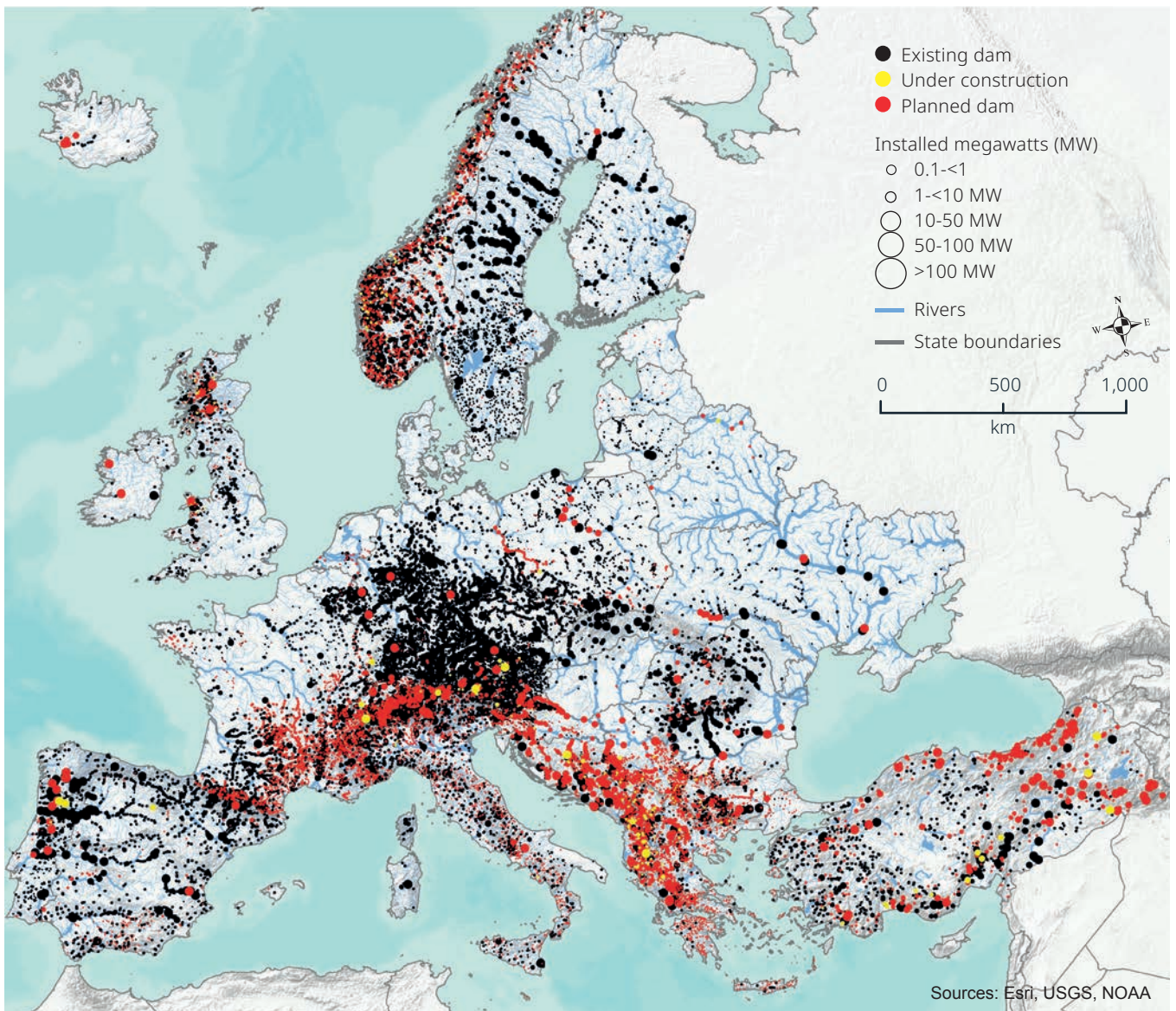


FIGURE 1: Hydropower plants for the whole of Europe

FIGURE 2: Distribution of hydropower plants for entire project area

- Existing
- Under construction
- Planned

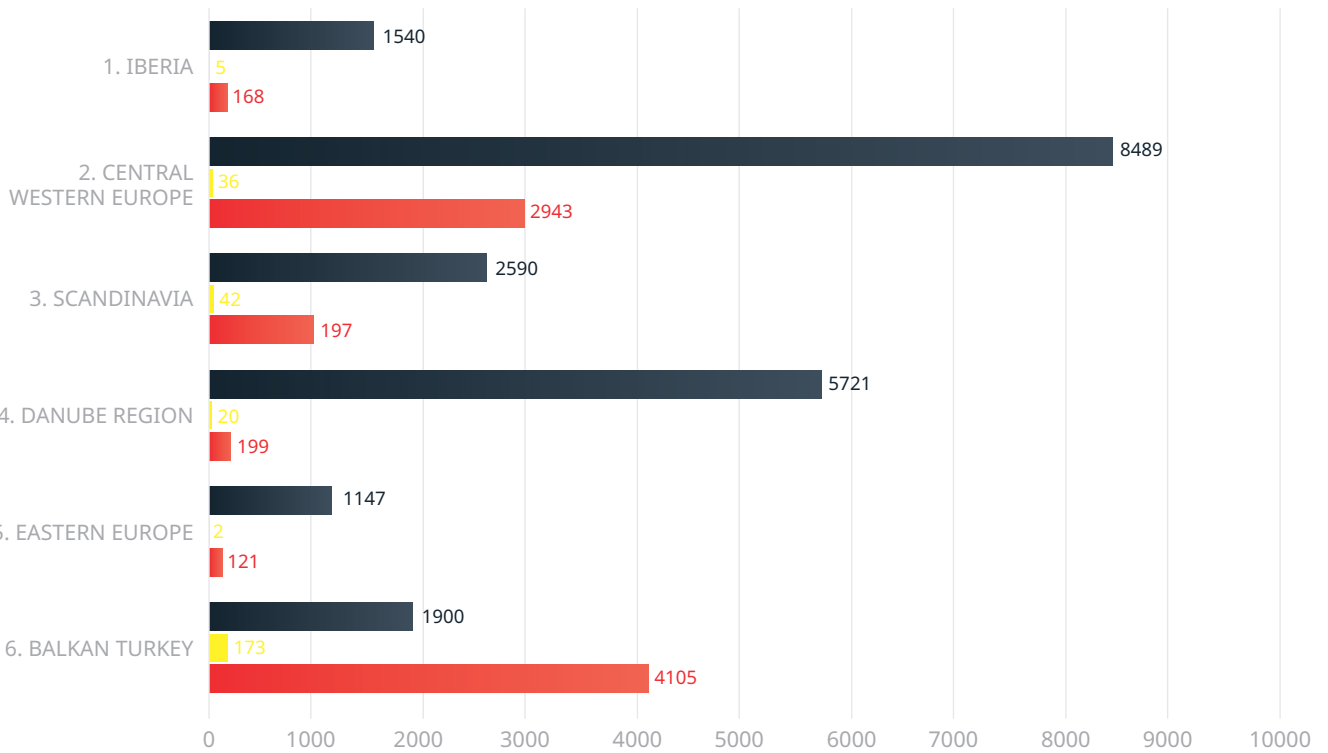
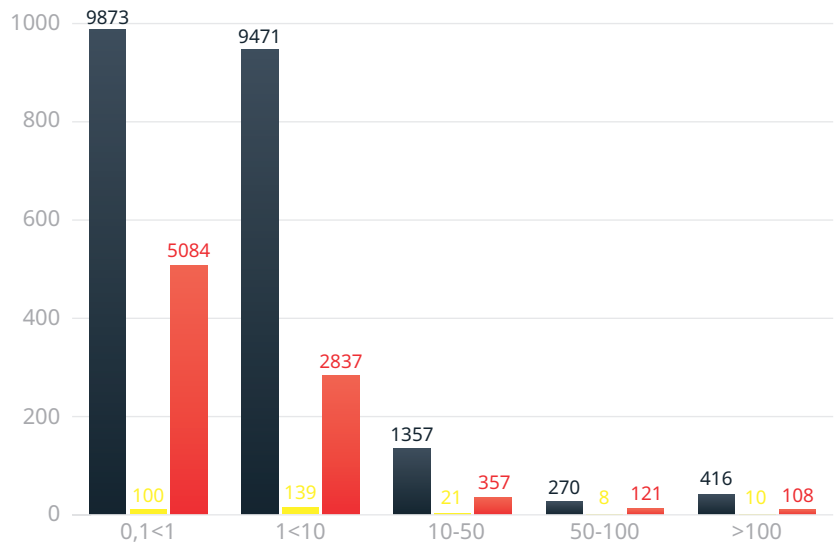


FIGURE 3: Region distribution of hydropower plants for entire project area.

- Existing
- Under construction
- Planned

As mentioned earlier in the Methodology section, the number of existing and planned small and micro hydropower plants is difficult to determine. In Austria, for example, a total of 5,200 hydropower plants are officially recorded. Around 1,000 of these are micro hydropower plants, and were therefore not covered by this study. In addition to the 19 plants under construction, this study has recorded an additional 123 planned hydropower plants of various size classes. The additional 800 planned small hydropower plants recorded by the Small Hydropower Association (but without precise GIS coordinates) were not included in this study. Looking in more detail, only 3,036 hydropower plants are currently delivering energy into the public grid and therefore can be assumed to have “larger” turbines (> 0,1 MW). However, there are private users that use engines above this limit. As there is no public data to distinguish between the small and micro hydropower plants, and to be able to keep data comparable, in this particular case many very small hydropower plants in the headwaters and in very close proximity were removed from the database.

This should underline the high pressure of all hydropower plants on small rivers across Europe.

3.2 OVERLAY OF PROTECTED AREAS

The map below (Figure 5) shows all protected areas in Europe. The compilation and grouping of the protected areas is a prerequisite to delivering precise counts, because many hydropower plants overlap with several protection types. In this case, only the higher category is counted (e.g. if a National park, ranked in a higher protection category, is at the same time a Natura 2000 site, a lower protection category).

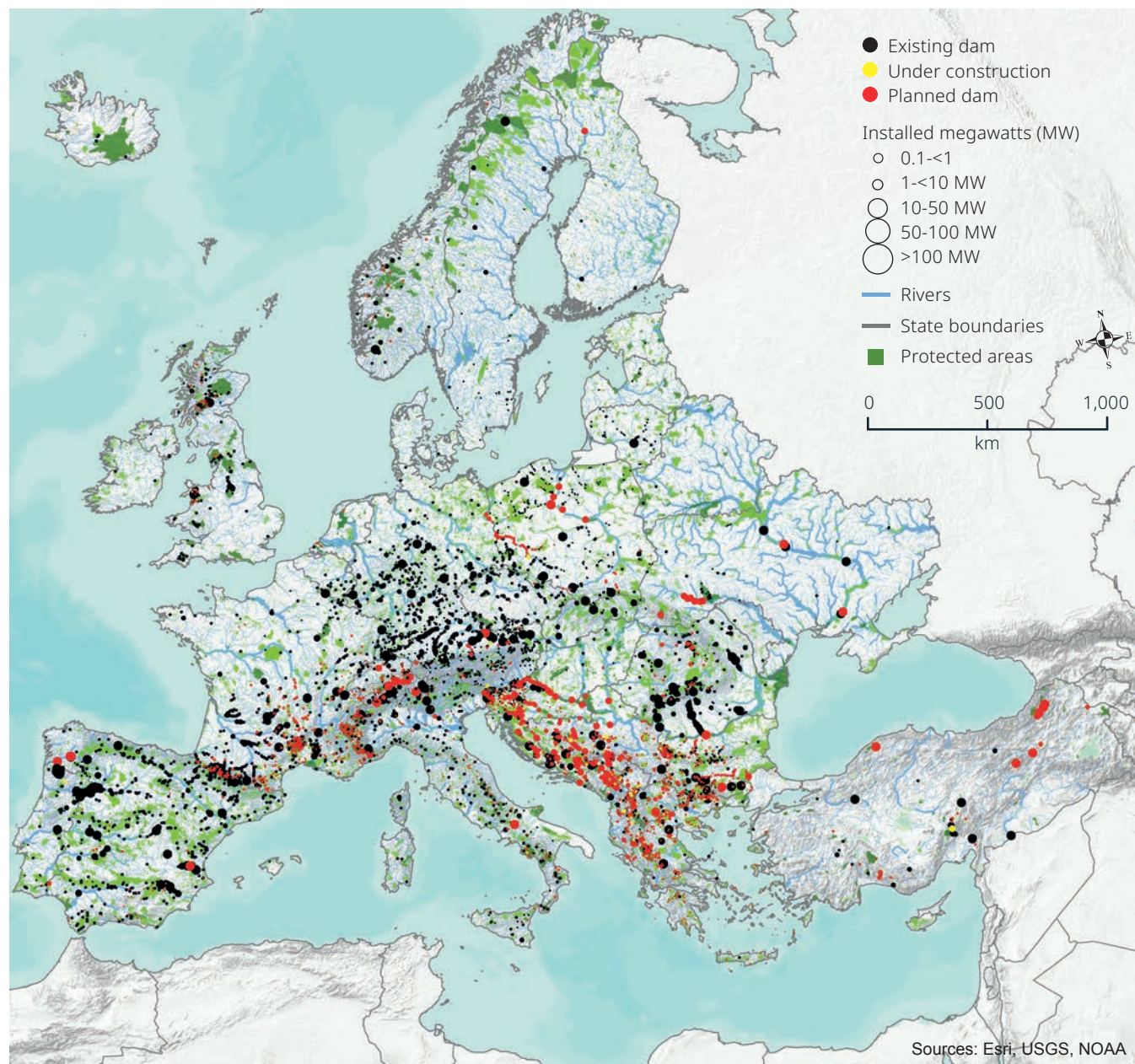


FIGURE 4: Hydropower plants in Europe in protected areas. The protected areas have been categorised as follows:

Category 1: National parks, Ramsar sites, World Heritage sites, biosphere reserves

Category 2: Natura 2000, Emerald areas for Eastern Europe, nature reserves

Category 3: Landscape protection

In Europe, the Natura 2000 network includes many rivers and their valleys, however it also includes impoundments, and the protection purpose is not always focused on the rivers. A study done by BOKU University found that in the alpine areas a total of 937 km of river units are in at least good status but are not under protection. In the non-EU South-Eastern and Eastern European countries, several important river valleys are also not protected so far. In Turkey, protected areas in river valleys are non-existent to a large extent. Additionally, not all protected areas serve as specific river protection areas. Significant gaps in protection corridors regarding rivers can be found in Eastern Europe and Turkey.

In total 6,409 hydropower plants can be found in protected areas, accounting for 21% of all hydropower plants in Europe. These are subdivided into 2,396 planned hydropower plants, 77 hydropower plants under construction and 3,936 already existing. In total 4,610 hydropower plants are located in Natura 2000 sites.

FIGURE 5: Hydropower plants in protected areas

- Existing
- Under construction
- Planned

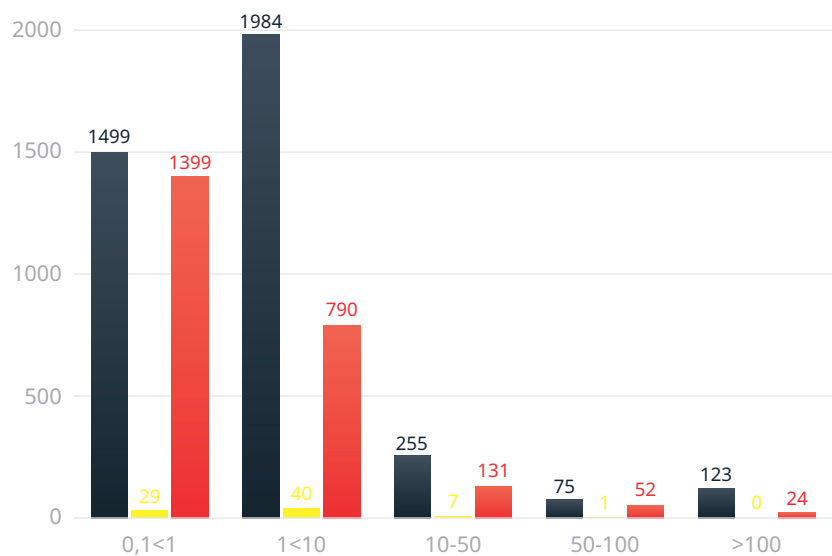


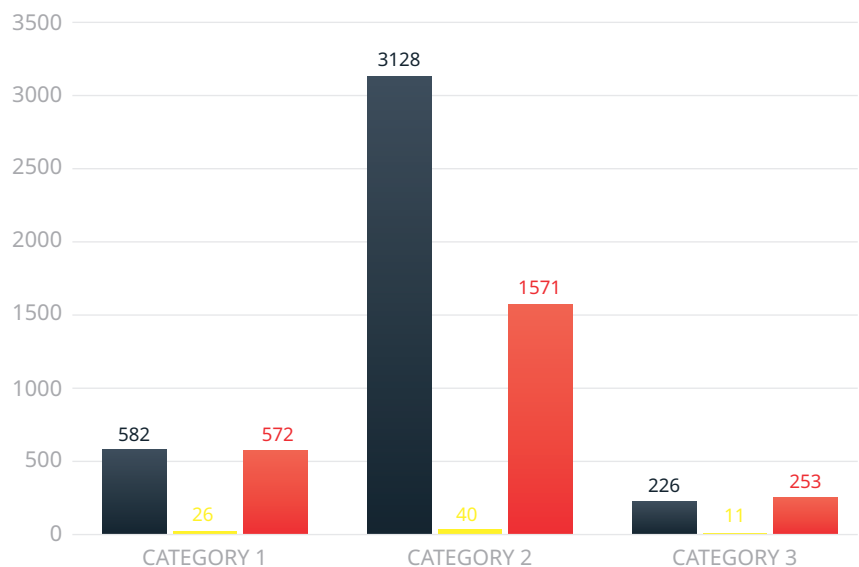
FIGURE 6: Hydropower plants in Europe in protected areas. The protected areas have been categorised as follows:

Category 1: National parks, Ramsar sites, World Heritage sites, biosphere reserves

Category 2: Natura 2000, Emerald areas for Eastern Europe, nature reserves

Category 3: Landscape protection)

- Existing
- Under construction
- Planned



3.3 COUNTRY OVERVIEW

3.3.1 Iberian Peninsula

Countries included: Andorra, Portugal, Spain

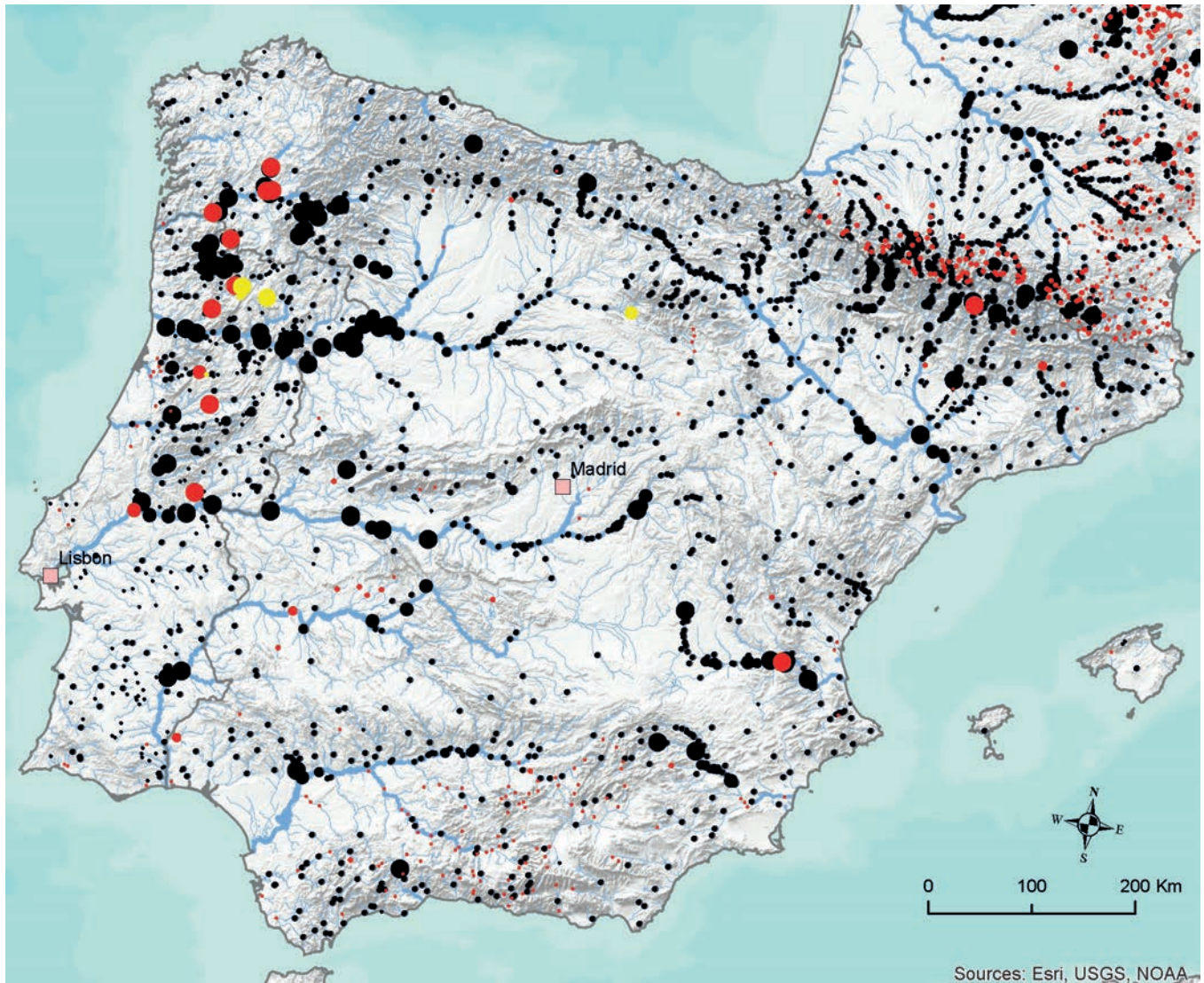


FIGURE 7: Hydropower plants for the Iberian peninsula

- Existing dam
 - Under construction
 - Planned dam
- Installed megawatts (MW)
- 0.1-<1
 - 1-<10 MW
 - 10-50 MW
 - 50-100 MW
 - >100 MW
- Rivers
 - State boundaries

On the Iberian Peninsula in particular, the major rivers in Portugal and Spain are intensively used for hydropower, specifically the lower and middle courses of Tajo and Duero, and the lower to middle course of Ebro which have been turned into long and continuous impoundment cascades. Portugal is one of the few countries in Western Europe still planning large dams on tributaries instead of focusing on pumped storage or refurbishment of existing turbines.

It should also be noted that not all existing dams are mapped for the Iberian Peninsula, in which the majority of dams are in fact for irrigation/water abstraction. The current assessment has focused on the biggest rivers (>100 km stretch) and did not account for the remaining tributaries.

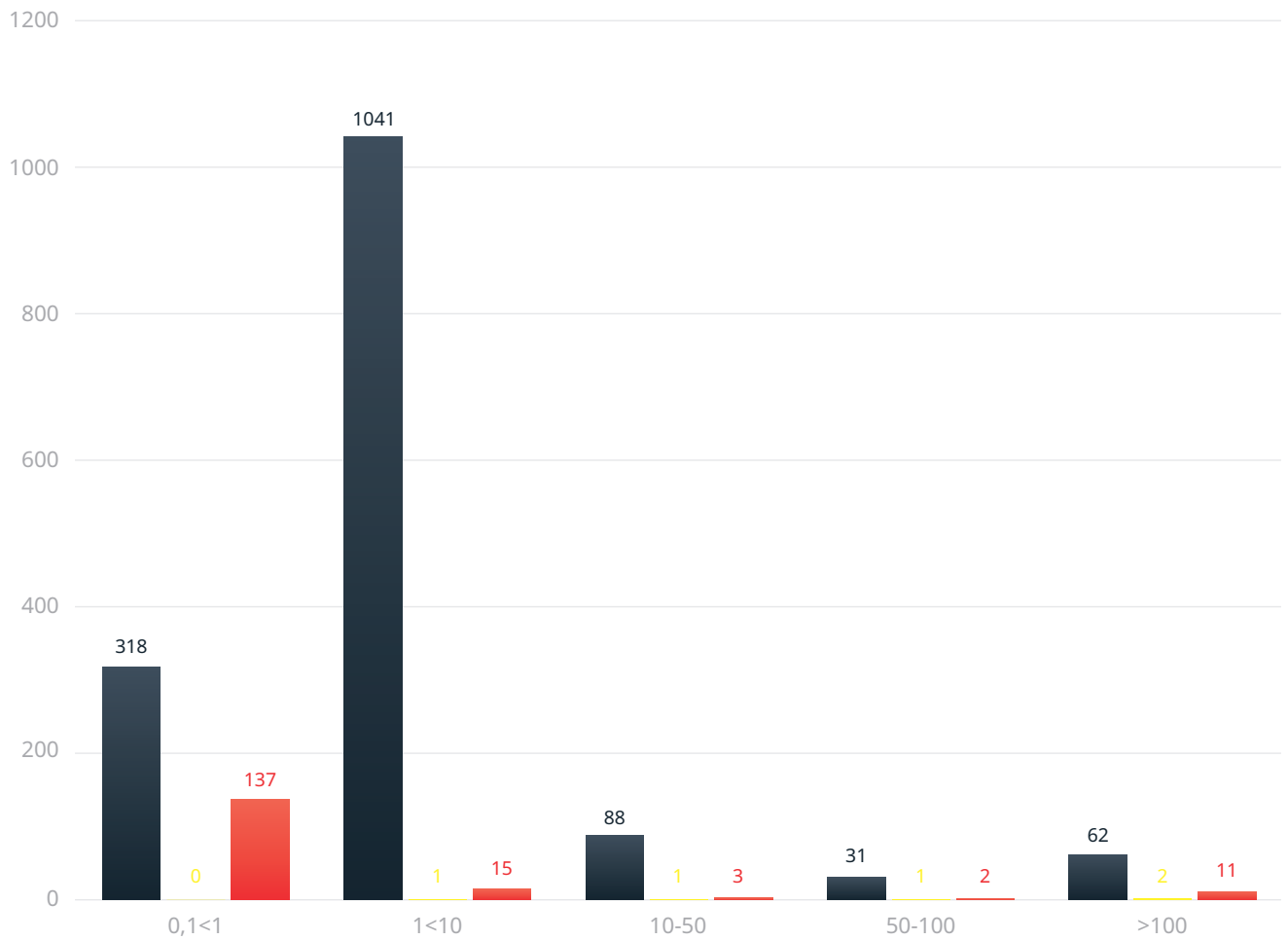


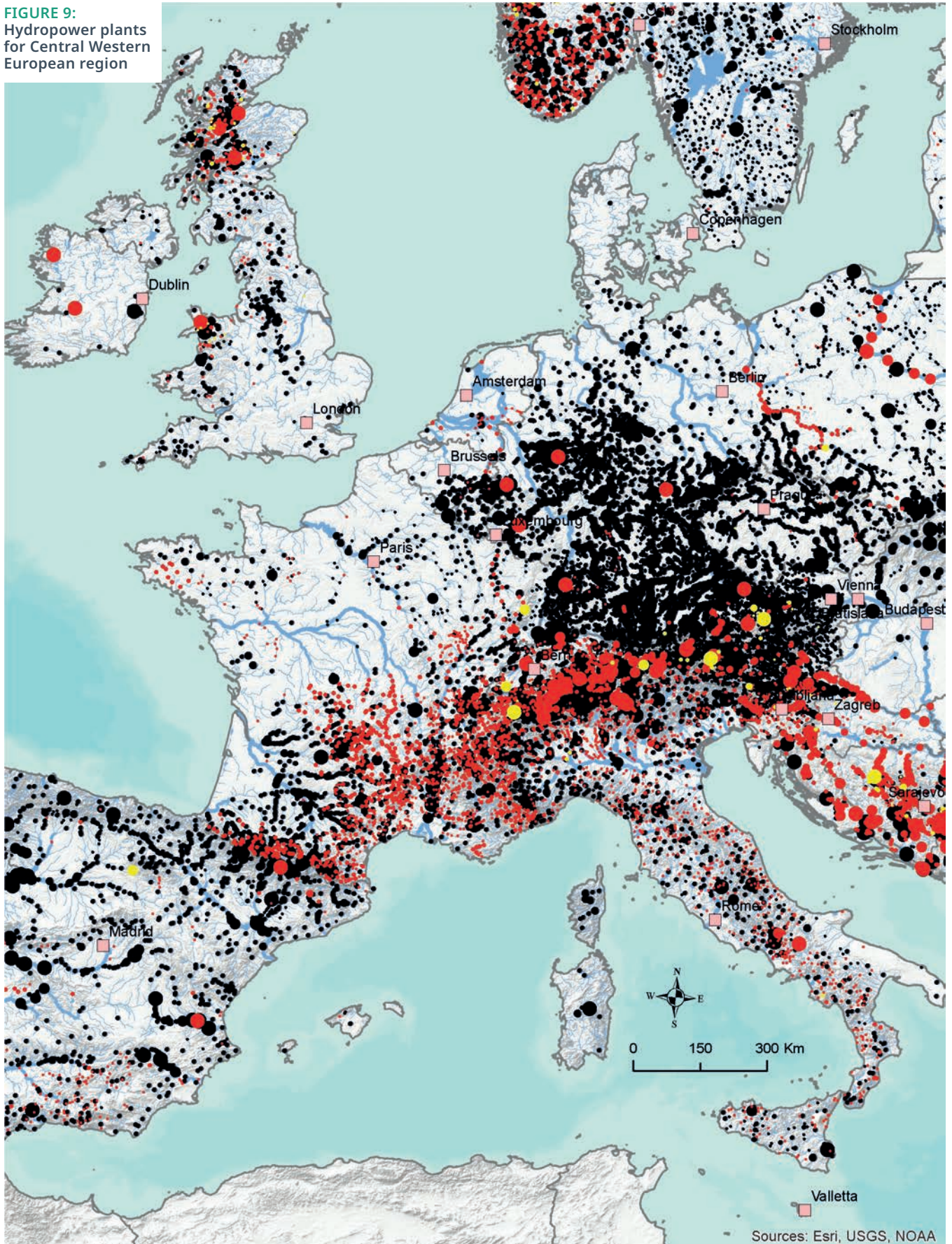
FIGURE 8: Distribution of hydropower plants for the Iberian peninsula

- Existing
- Under construction
- Planned

3.3.2 Central Western European region

Countries included: Belgium, France, Germany, Ireland, Italy, Luxembourg, Malta, Monaco, the Netherlands, San Marino, Switzerland, United Kingdom

FIGURE 9:
Hydropower plants
for Central Western
European region



Switzerland is the country with the highest hydropower exploitation, followed by France and Italy. Almost all rivers in the mountainous regions are used for hydropower production. The Alpine arc in particular is densely covered by hydropower plants. Whilst many of these plants are storage and diversion plants represented by one dot, they can have many extraction and storage sites which broadens their impact. Pumped storage hydropower plants are also already in place or currently under development to use the advantage of huge height differences in the mountains. In Germany, although hydropower meets a lower share of the overall energy demand, most of the rivers in the South and centre of the country are densely covered by hydropower plants. Austria is amongst the countries with the highest overall number of existing hydropower plants and several new ones are still planned.

Most of the plants in this region (4,583 existing ones) are small hydropower plants.

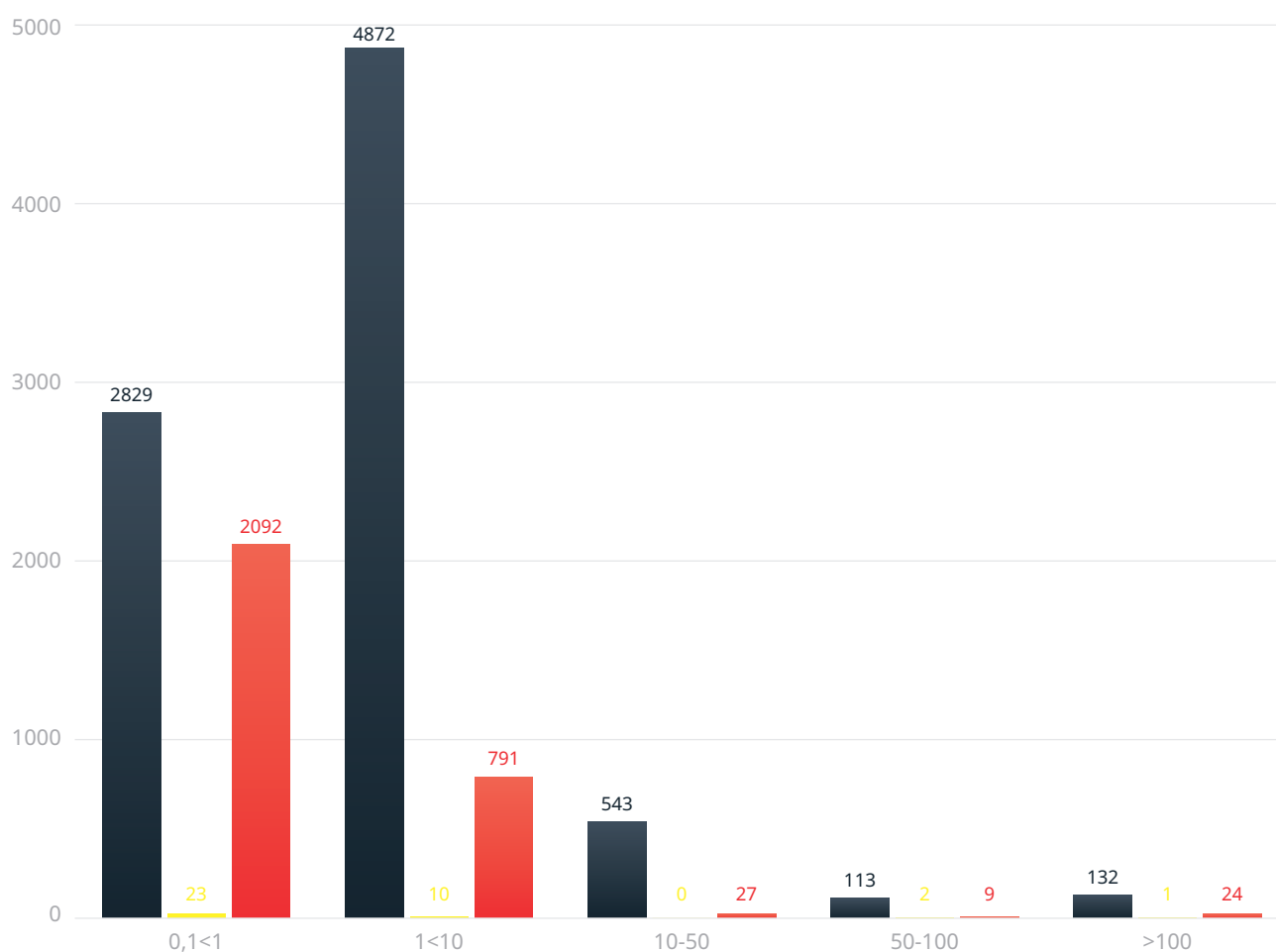


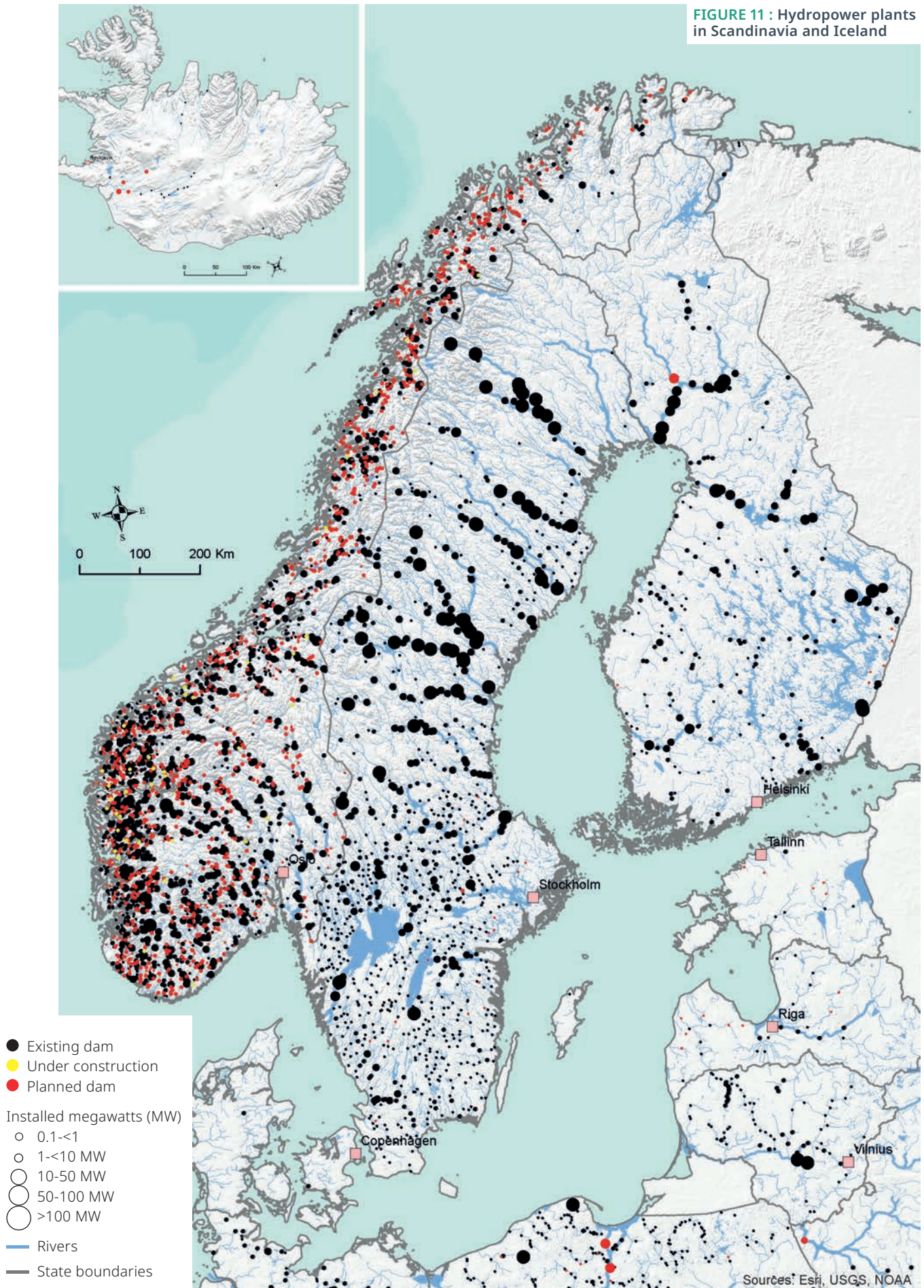
FIGURE 10: Distribution of hydropower plants for Central Western European region

In Switzerland, there are plans to increase the existing hydropower capacity, by, for example, raising the water levels in huge mountainous reservoirs. A new kind of storage lake could be fed by melting glaciers to make so called periglacial hydropower plants (there are 7 main glacier projects currently shortlisted). All very large projects (> 100 MW) are pumped storage. Whilst many hydropower plants on rivers are foreseen for refurbishment and for licence expansion, improvement of efficiency, higher ecological standards and reduction of losses of residual water are under discussion.

3.3.3 Northern European region, Scandinavia

Countries included: Denmark, Finland, Iceland, Norway, Sweden

FIGURE 11 : Hydropower plants in Scandinavia and Iceland



Norway, together with Switzerland, is the country which meets the highest share of its electricity demand using hydroelectricity. All rivers, even in the more densely settled southern part of the country, are already exploited. In Sweden, the density of hydropower plants is slightly lower than in Norway and the more gently sloped Finland has the smallest number of hydropower plants. In Sweden and Finland, both EU Members, the environmental obligations are higher and the focus is set on refurbishment, compared to Norway which is still planning many new small plants. Iceland is also planning some bigger hydropower plants.

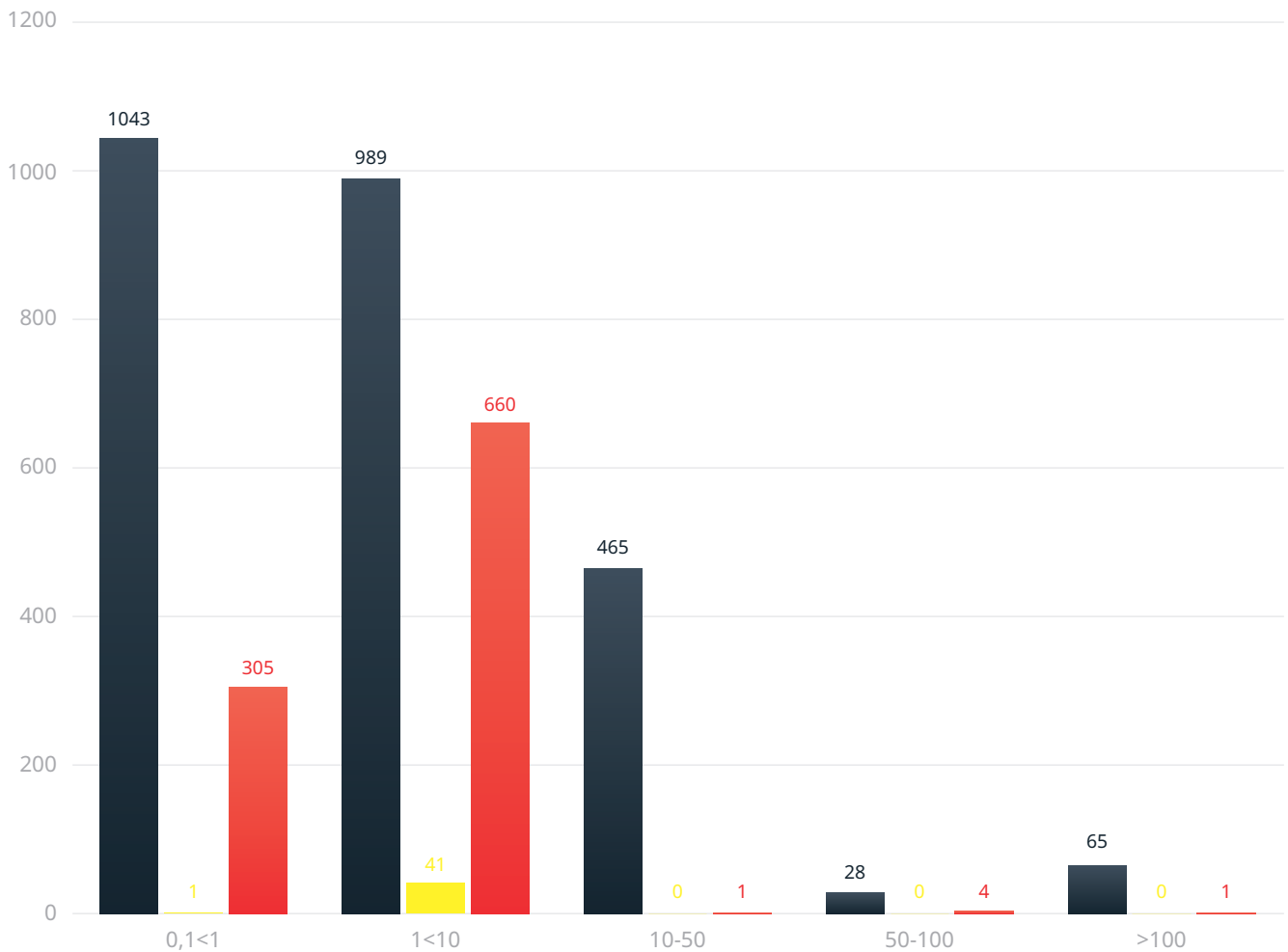


FIGURE 12: Distribution of hydropower plants for Scandinavia region

- Existing
- Under construction
- Planned

3.3.4 Central Eastern Europe, Danube region

Countries included: Austria, Czech Republic, Hungary, Romania, Slovakia

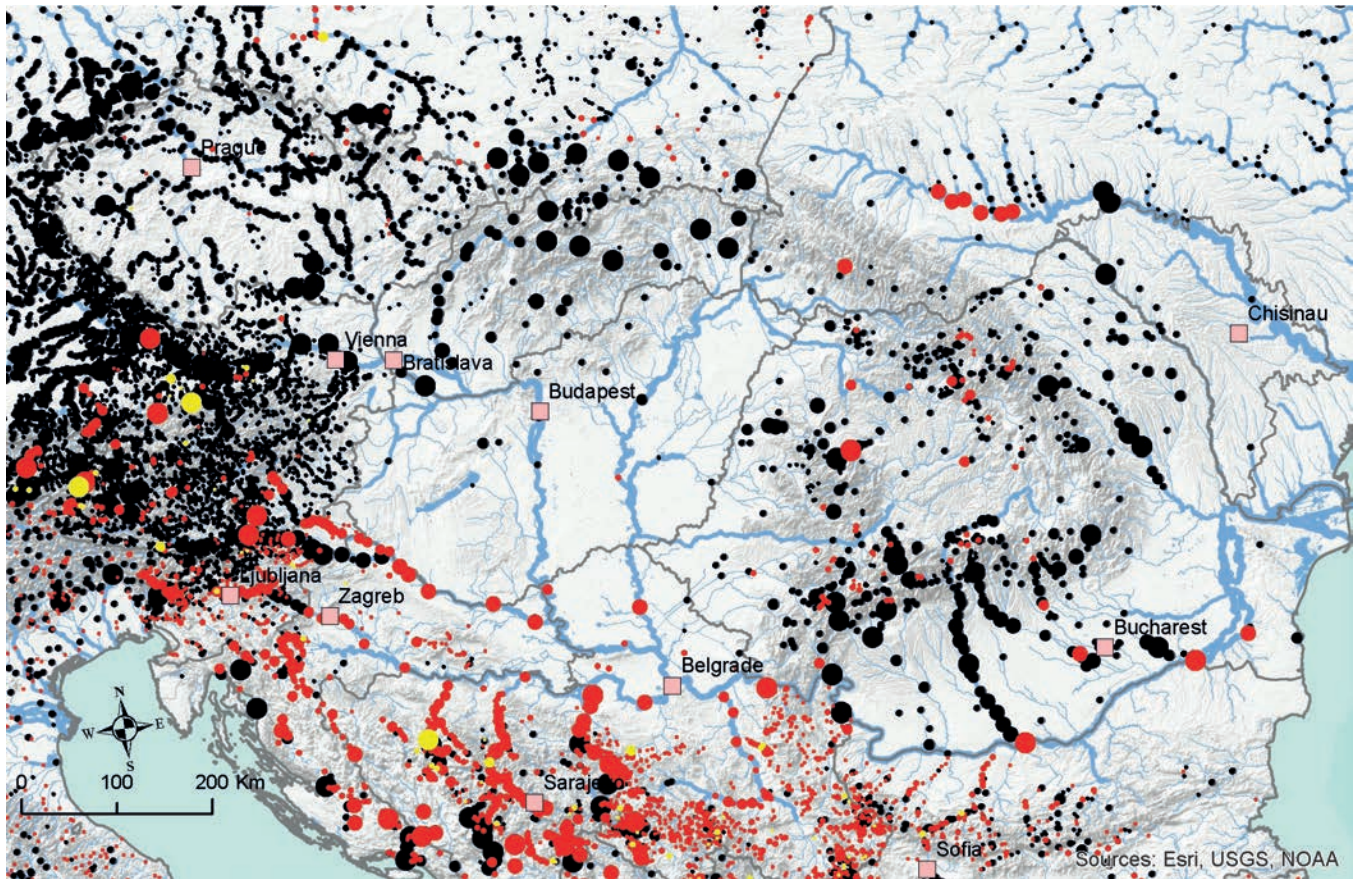


FIGURE 13: Hydropower plants for the Danube region

- Existing dam
 - Under construction
 - Planned dam
- Installed megawatts (MW)
- 0.1-1
 - 1-10 MW
 - 10-50 MW
 - 50-100 MW
 - >100 MW
- Rivers
 - State boundaries

In the Danube region, ambitious plans for expansion of the already exploited capacity exist in almost all countries. Together with parts of southern Germany and the Balkans, the Danube catchment is becoming one of the most affected large river catchments not only in Europe but also worldwide. The environmental opposition against new dams is high. Nevertheless, in Bavaria and Austria new hydropower plants are planned. Some of the projects on larger rivers might be suspended such as those on the lower Drava, where the recently designated 5-country biosphere reserve Mura-Drava-Danube managed to change the narrative. Numerous new projects are however appearing on medium-sized rivers in the Balkan countries and some on Romanian rivers. Several dams were built in the past decade such as on the Sava in Slovenia. Regarding small hydropower plants, the Czech Republic has the highest concentration amongst the Central and Eastern European countries.

Hydropower development only started in Romania in the 1960s. Projects that have been built since then include the Iron Gate hydropower plant, constructed together with Serbia. The Olt river, originating in the Carpathian mountains, is covered by a long chain of hydropower plants. Nowadays, the Jiu river is also being used extensively. The plans for two large dams in the lower Danube, which date as far back as the Soviet rule, have re-appeared on the political agenda of Romania and Bulgaria in recent years.

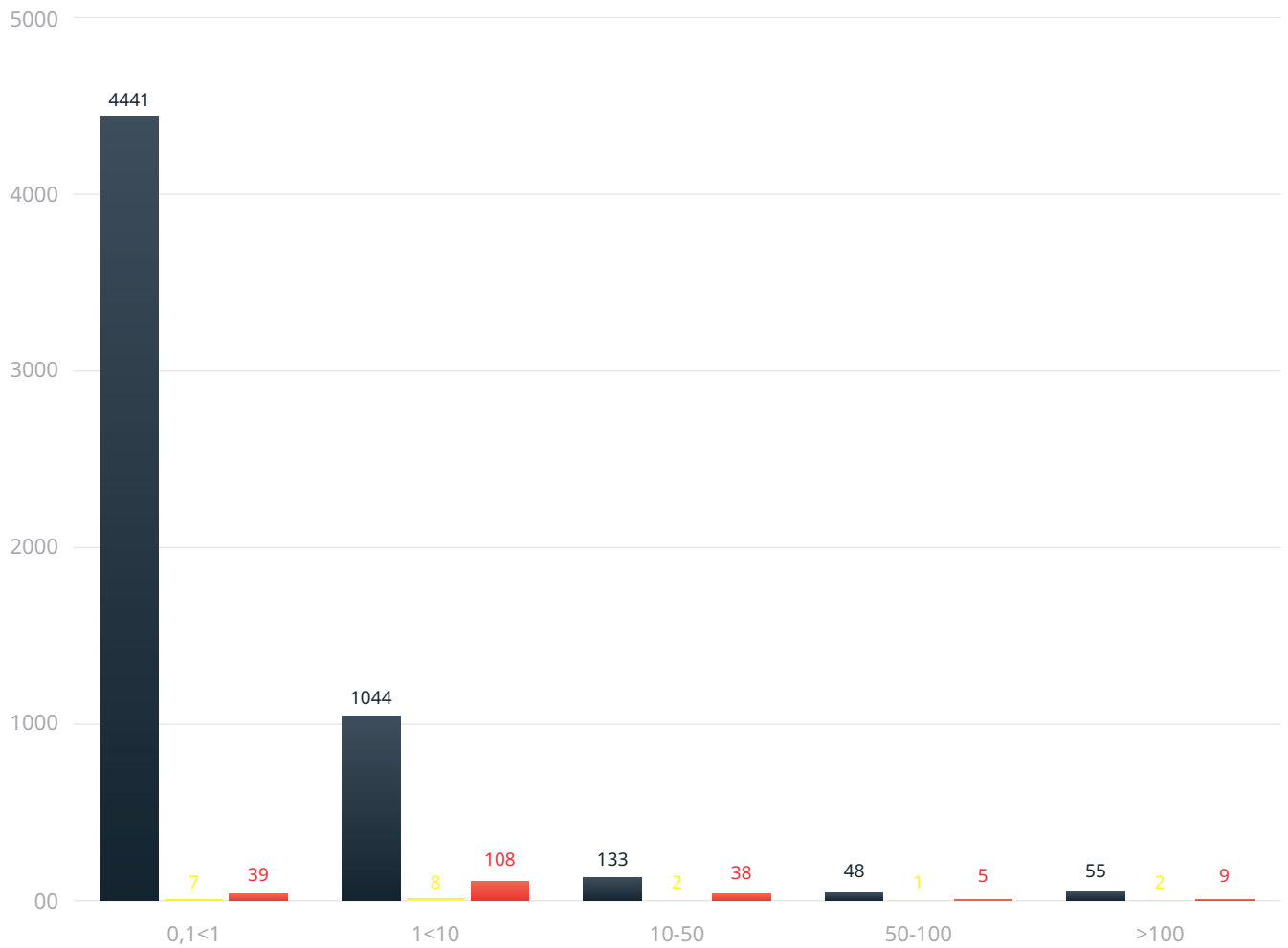


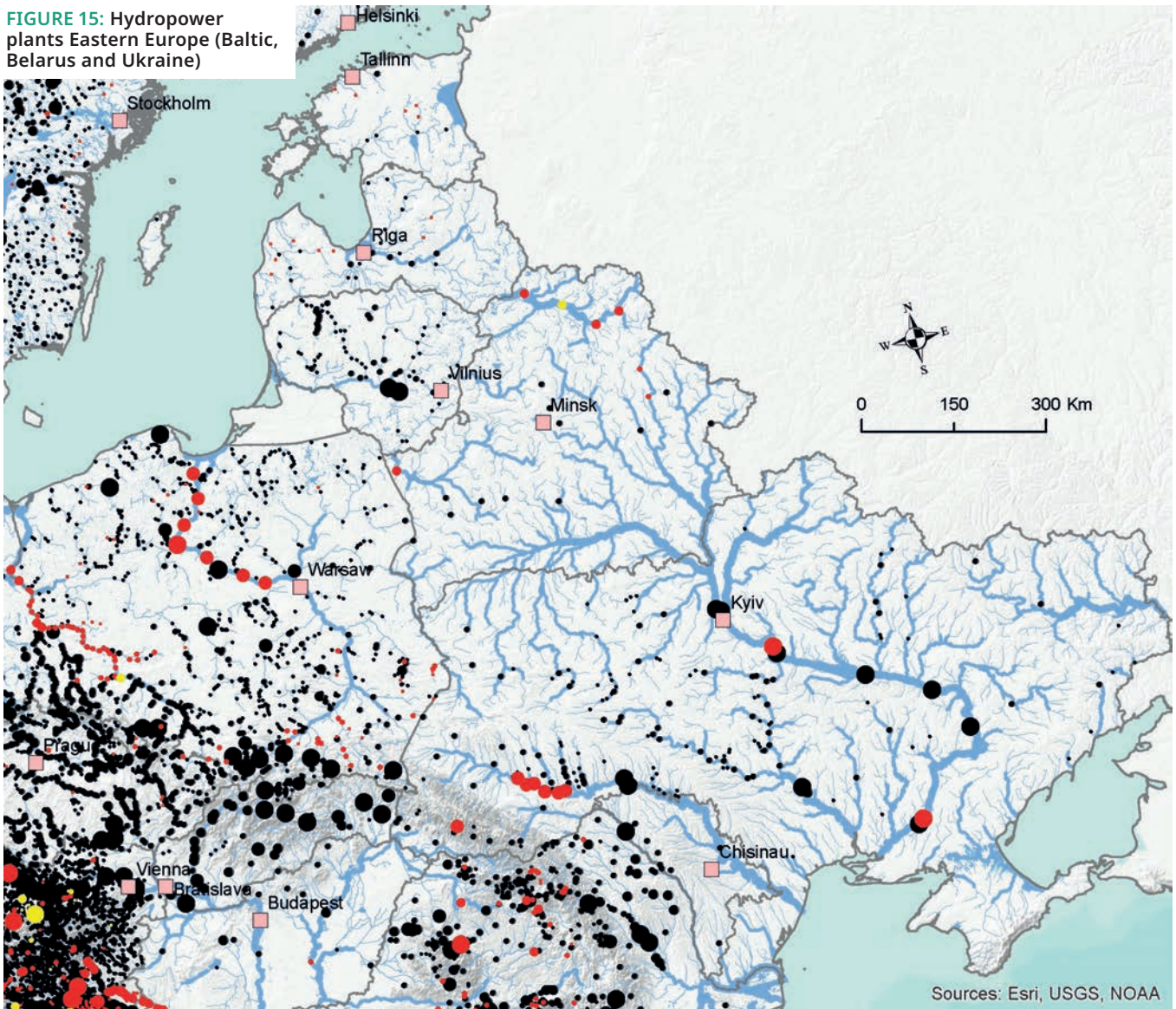
FIGURE 14: Distribution of hydropower plants for the Danube region

- Existing
- Under construction
- Planned

3.3.5 Eastern European region with Baltic countries

Countries included: Belarus, Estonia, Latvia, Lithuania, Moldova, Poland, Ukraine

FIGURE 15: Hydropower plants Eastern Europe (Baltic, Belarus and Ukraine)



- Existing dam
 - Under construction
 - Planned dam
- Installed megawatts (MW)
- 0.1-1
 - 1-10 MW
 - 10-50 MW
 - 50-100 MW
 - >100 MW
- Rivers
 - State boundaries

Hydropower plants in these eastern and mostly flat countries are focused on bigger rivers and in mountainous regions, such as in southern Poland and the Carpathian mountains in the Ukraine. In southern Poland and parts of Ukrainian Carpathians, the development of small hydropower plants is increasing (e.g. upper Tisa and Prut basins). Multiple larger plants are also foreseen on the upper reaches of the Dnister. The refurbishment and expansion of existing impoundments on the Dnjpr and the Dnjestr and additional usage for pumped storage will increase exploitation. In southwestern Ukraine, another 300 small hydropower plants are planned. These are mostly in less altered mountainous streams, but the locations are currently not defined. In Poland, many additional small hydropower plants are envisaged, although not exclusively using existing structures.

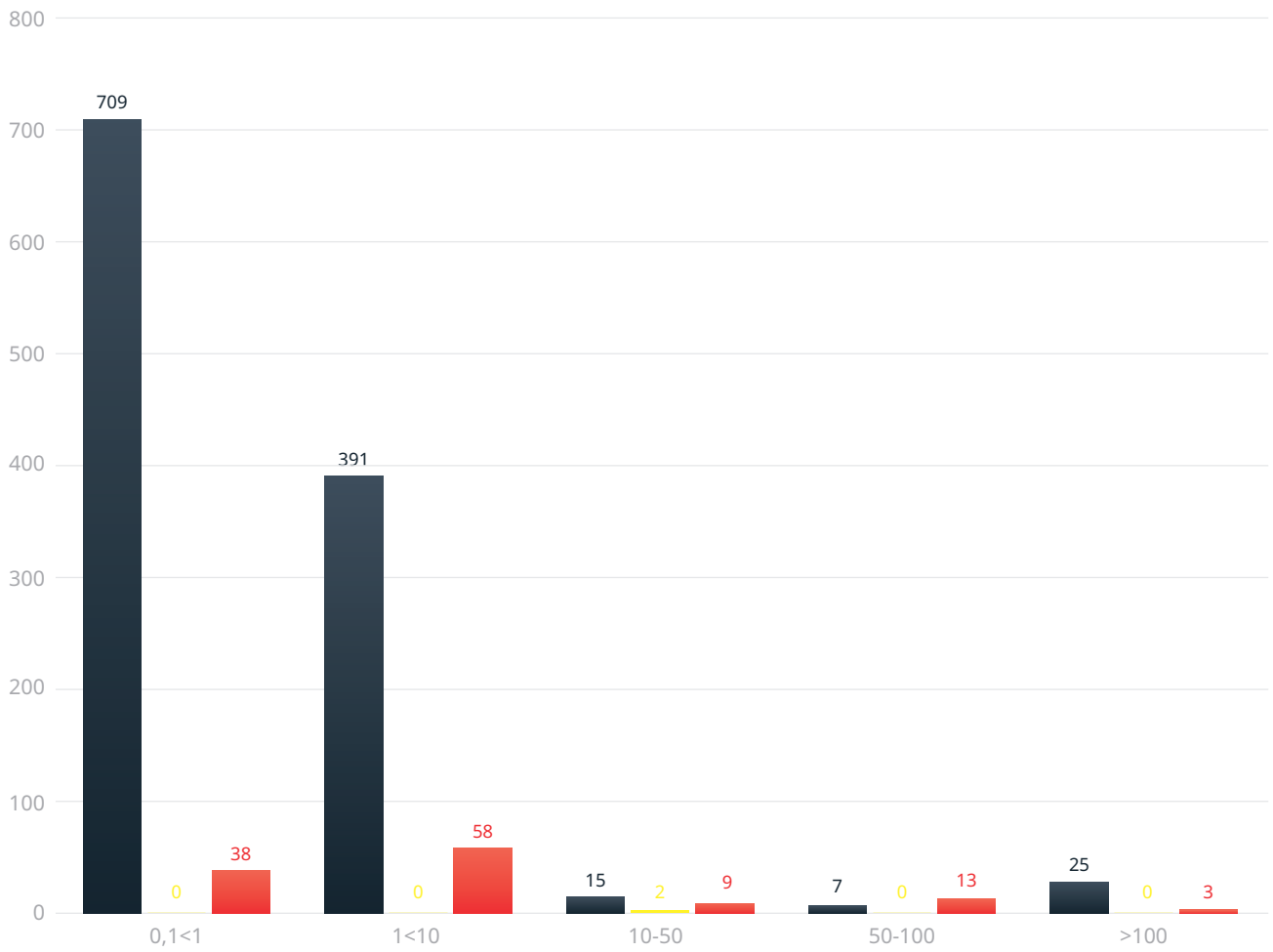


FIGURE 16: Distribution of hydropower plants for Eastern Europe

- Existing
- Under construction
- Planned

3.3.6 Balkan and Eastern Mediterranean region

Countries included: Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Greece, Kosovo, Macedonia, Montenegro, Serbia, Slovenia, Turkey

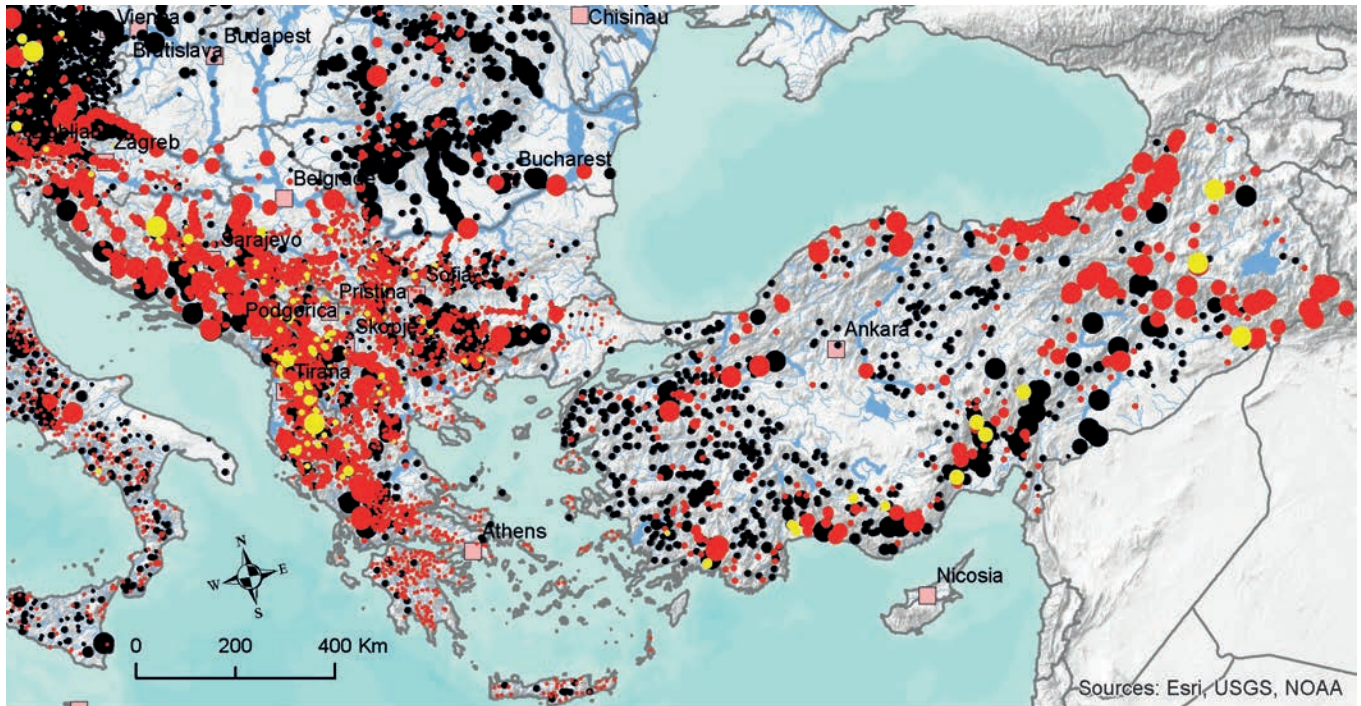


FIGURE 17: Hydropower plants for Balkan and Eastern Mediterranean region and Turkey

- Existing dam
 - Under construction
 - Planned dam
- Installed megawatts (MW)
- 0.1-<1
 - 1-<10 MW
 - 10-50 MW
 - 50-100 MW
 - >100 MW
- Rivers
 - State boundaries

In some rivers, such as those in the water-rich Neretva, Drina and Drin river valleys, hydropower development began in the 1960s. Many new dams are currently under construction and planned in Albania and Bosnia-Herzegovina, all on larger rivers. Albania in particular has the highest rate of new developments in the hydropower sector.

Turkey has one of the most ambitious hydropower plans for 2020 and 2030. The number of existing hydropower plants, 490, will be increased by an additional 534 hydropower plants nationally. Whilst in Western Europe the development of new “run of the river” plants on larger rivers has stalled or have been completed (65% of the potential is used), Turkey aims to increase its potential from 50% to 80% (IHA 2018).

FIGURE 18: Distribution of hydropower plants for Balkan and Eastern Mediterranean region and Turkey

- Existing
- Under construction
- Planned

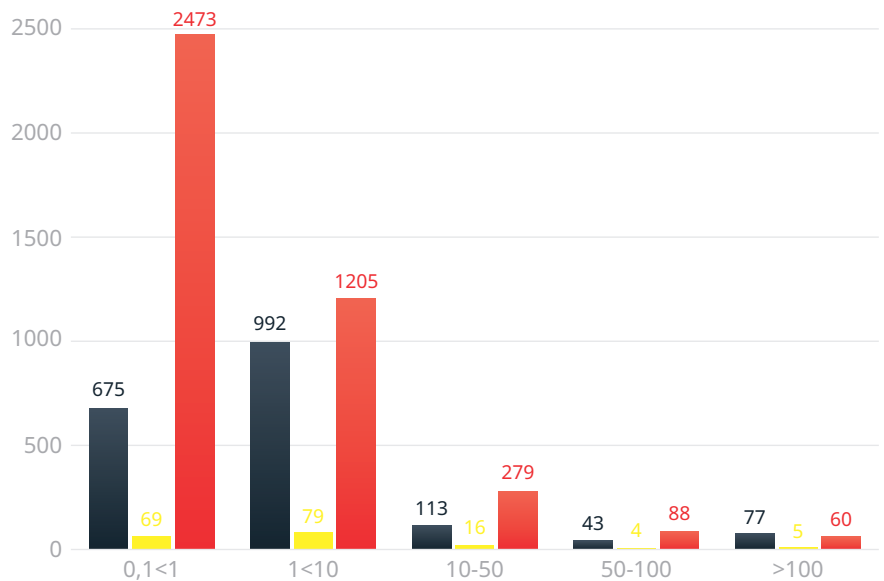


FIGURE 19: Moglicë hydropower plant (172 MW, build by Statkraft Norway) under construction in Albania on Devoll River, Albania (Google Earth, Digital Globe 2019).



3.3.7 Country overview in numbers

To allow a country-specific analysis, the following table summarises the distribution of hydropower plants.

TABLE 1: Hydropower plant distribution by country (colours indicate the 6 regions), status and size

Country	Existing					Planned					Under construction					Total
	0,1- <1	1-<10	10-50	50-100	> 100	0,1- <1	1-<10	10-50	50-100	> 100	0,1- <1	1-<10	10-50	50-100	> 100	
Albania	58	103	11	3	4	177	241	25	9	1	22	30	7		1	692
Austria	4007	253	38	18	27	19	61	32	3	8	6	8	2	1	2	4485
Belarus		13					2	4					1			20
Belgium	20	127	4	3	2	7										163
Bosnia and Herzegovina	41	45	3	3	9	84	158	53	12	5	5	6	1		1	426
Bulgaria	159	102	15	5	9	217	115	3	3	3		5				636
Croatia	12	26	9	3	7	46	63	29	9	2	1	1				208
Czech Republic	260	436	20	4	4	7	3				1					735
Denmark		2														2
Estonia	4	1				5										10
Finland	65	92	28	14	10	6			1							216
France	148	1009	42	21	30	830	580	2						1		2663
Germany	2135	2266	337	39	25	14	11	4	1	6		1				4839
Greece	14	65	4	2	10	898	150	8		5	3	5	1			1165
Hungary	2	12	2				1									17
Iceland		18							3	1						22
Ireland		13			1					2						16
Isle of Man		1														1
Italy	143	717	24	6	21	781	54	1	1	2		3				1753
Kosovo	2	8	2			12	58	4	1	2	1	15				105
Latvia	16	5				8										29
Liechtenstein			1													1

Country	Existing					Planned					Under construction					Total
	0,1- <1	1-<10	10-50	50- 100	> 100	0,1- <1	1-<10	10-50	50- 100	> 100	0,1- <1	1-<10	10-50	50- 100	> 100	
Lithuania	53	25			2											80
Luxembourg		5			1											6
Macedonia	47	38	5	1	2	118	52	14	4	1	9	5				296
Malta						1										1
Moldova		8	1													9
Montenegro	3	13			2	14	56	11	9	2	2	1				113
Netherlands	5	3	3			21	8									40
Norway	408	734	317	5	3	284	659	1			1	41				2453
Poland	553	267	12	7	13	25	56	5	6	1			1			946
Portugal	151	139	14	8	21	15			2	4		1	1		2	358
Romania	163	335	55	22	17	13	43	6	2	1						657
Serbia	43	32	3	2	5	698	107	17	5	3	21	9	1			946
Slovakia	9	8	18	4	7											46
Slovenia	288	30	15	6	3	184	26	30	1		4	1				588
Spain	167	902	74	23	41	122	15	3		7				1		1355
Sweden	570	143	120	9	52	15	1									910
Switzerland	213	395	103	39	45	294	110	20	7	10	1			1	1	1239
Turkey	8	530	46	18	26	25	179	85	35	36	1	1	6	4	3	1003
Ukraine	83	72	2		10				7	2						176
United Kingdom	165	336	29	5	7	144	28			4	22	6				746
Total	10015	9329	1357	270	416	5084	2837	357	121	108	100	139	21	8	10	30172

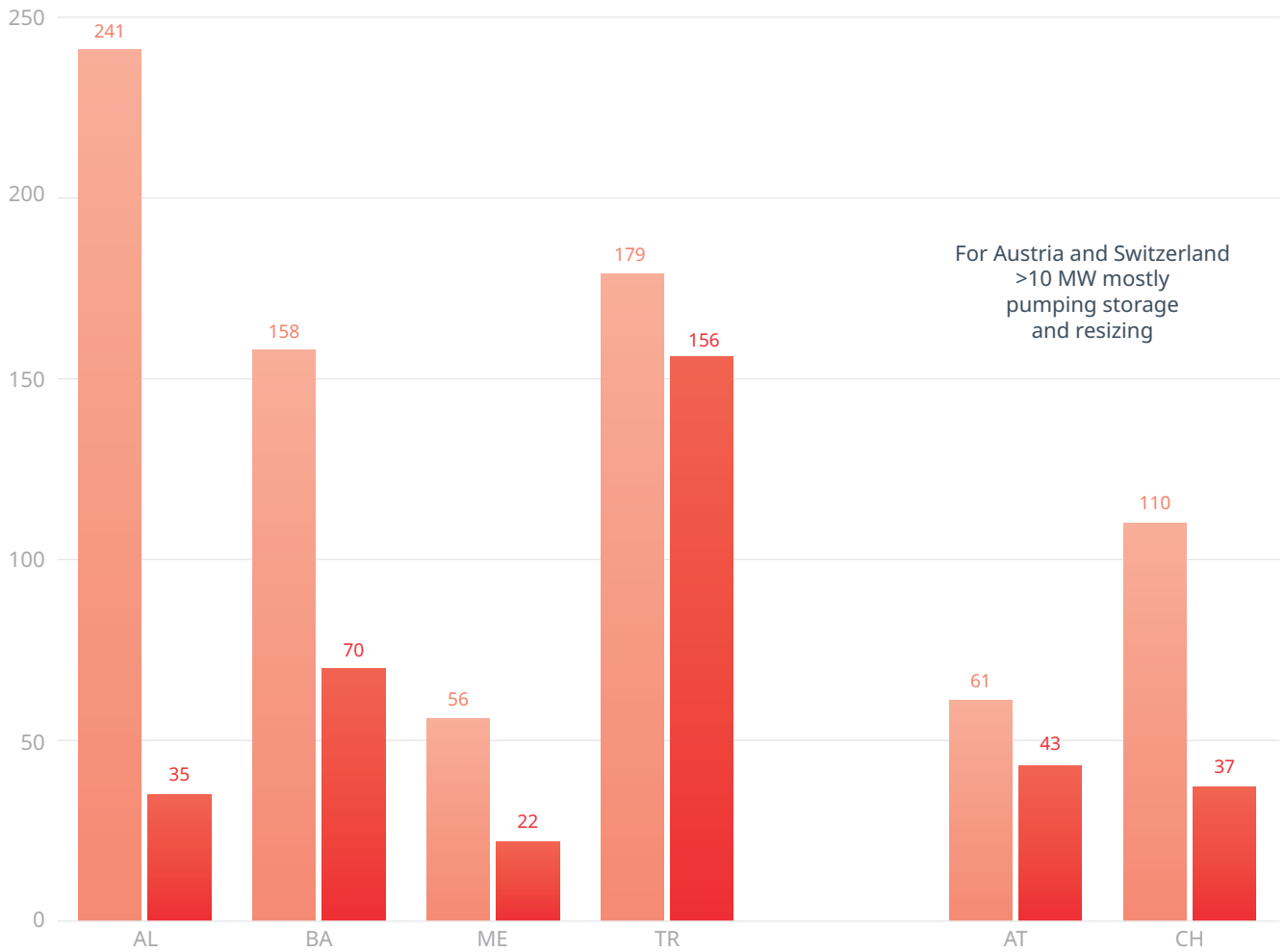


FIGURE 20: Selected countries (Albania, Bosnia & Herzegovina, Montenegro and Turkey representing the most dynamic development, whilst Austria and Switzerland have ambitious plans to increase size of existing and to build new pumping storage plants (Portugal and Scotland are also amongst the countries building many new hydropower plants).

- Planned HPP 1-10 MW
- >10 MW

4

CONCLUSION

THE NUMBER OF EXISTING AND PLANNED HYDROPOWER PLANTS > 0,1 MW (ABOUT 30,000) IS ALREADY EXCEPTIONALLY HIGH IN EUROPE AND THE TECHNICAL POTENTIAL OF HYDROPOWER IS ALREADY USED TO A LARGE EXTENT IN MANY AREAS

This inventory shows that the already large hydropower presence in Europe is being further increased by hydropower development in most regions of Europe.

The density of hydropower plants in Western Europe is exceptionally high. The development of hydropower is mixed across Europe. The Balkan countries, in particular Albania, still have many hydromorphologically intact rivers—but these free-flowing rivers are at great risk given the rapid development of dams in the region. In northern Europe and Scandinavia, Scotland and Norway have the most ambitious plans (mostly small hydropower plants), whilst in Eastern Europe, Poland and Ukraine will develop not only small hydropower plants, but also larger dams on the Vistula, Odra or Dnstr. The Balkans and Turkey have ambitious plans to significantly raise their exploitation. In the Iberian peninsula, Central Western Europe and Central Eastern/Danube, hydropower expansion plans also exist.

All future development will further disrupt major and medium rivers and valuable rivers or river stretches across all countries. Many of those rivers also fall in protected areas.

Regarding the protection of river valleys, the results are paradoxical: In EU countries, because many hydropower plants were already built before the designation of protected areas, even strongly altered rivers are protected, whilst in many other countries biodiversity rivers and culturally important rivers remain unprotected.

The analysis of protected areas shows though that even the status of protection does not prevent the development of new hydropower projects. In the Balkans, even the highest protection categories such as national parks are not excluded from hydropower plants and planning.

This study concludes:

- The number of existing and planned hydropower plants > 0,1 MW (about 30,000) is already exceptionally high in Europe and the technical potential of hydropower is already used to a large extent in many areas. In total 30,172 hydropower plants have been recorded, out of those 8,507 are projected/ planned, 278 are under construction and 21,387 already exist.
- The number of existing, under construction and planned hydropower plants and their overlap with protected areas (6,409) reveal a tremendous pressure on European rivers, even where they should be preserved. The majority of these plants were built before any environmental legislation was put in place and therefore do not adhere to any minimum environmental standards, such as the Water Framework Directive (WFD) or similar national legislation.
- The significant hydromorphological changes, also caused by hydropower plants, are responsible for the failure to reach the good ecological status of water bodies under the WFD in Europe. Hydromorphological changes are listed as the most common pressure on freshwater ecosystems according to the European Environment Agency. Dams are the most important deterioration factor for river continuity for biota and sediment. Impoundments affect long reaches upstream and turn rivers into reservoirs with partially stagnant conditions.

THE MAJORITY OF THESE PLANTS WERE BUILT BEFORE ANY ENVIRONMENTAL LEGISLATION WAS PUT IN PLACE AND THEREFORE DO NOT ADHERE TO ANY MINIMUM ENVIRONMENTAL STANDARDS, SUCH AS THE WATER FRAMEWORK DIRECTIVE (WFD) OR SIMILAR NATIONAL LEGISLATION

- The speed of hydropower development is at first glance rather slow (about 20-30 new plants each year). However, the rapid development in the past 10 years in the Balkans and in Turkey show how quickly free-flowing rivers can be turned into impoundments.
- The distribution of hydropower plants varies greatly between different European bioregions. Both the mountainous areas with large slopes and energy, and also the lower, slower flowing river stretches in the plains, have become exploited by hydropower. Nevertheless the distribution of hydropower plants is clearly correlated to mountainous relief (or river originating in high plains and cutting towards the sea through deep valleys) and areas with sufficient precipitation.
- The collection of data clearly shows the deficits of governmental records and assessment of hydropower plants, particularly for smaller projects. No comparable data sets across countries were available. It seems many of the small hydropower plants are only known by water book/licence, but even most of these inventories are incomplete and ecological assessments do not exist.

5

RECOMMENDATIONS

- New hydropower projects in the last remaining free-flowing or intact rivers in Europe have to be prevented. Within protected areas, hydropower development cannot be an option as it leads to the deterioration of river ecosystems. At the moment, even protected areas are not sufficiently protecting rivers.
- Due to the extremely high number of hydropower plants in all size classes and the large degree of already used hydropower potential, the planning of additional hydropower plants should be reconsidered. The increase of energy production by small hydropower plants is very limited, but the ecological impact in most cases are considerable. Another aspect that needs to be regarded is changing discharges due to climate change which increase uncertainties for many hydropower plants, such as in Portugal, the Balkans and Turkey.
- In countries with the highest density such as Austria, Norway or Switzerland, the focus should solely be on the refurbishment and where possible on renovation by increasing efficiency of already existing hydropower plants without further deterioration of the hydromorphological conditions. Licences which need to be renewed in the coming years and decades must require restoration efforts.
- Old hydropower licenses which need to be prolonged must require strong criteria on how to mitigate the environmental impacts and the public must be included in this evaluation.
- Integrated river and catchment approaches (continuity) are necessary to further assess dams also in the neighbourhood of protected areas.
- The restoration or mitigation of hydropower impacts is very expensive in comparison to the ecosystem services of free-flowing rivers. Restoration is necessary but can never substitute the protection of the last intact rivers.
- Dams have to be considerably improved to allow biota to pass the obstacle and to allow suspended sediments and in particular bedload to pass the dams.
- Hydropower must be understood as a transitional energy source supporting energy transitions, but it should be clear the middle-term energy future must rely on other sources (such as solar and wind), combined with improved energy efficiency and reduction of energy demand. Water sources but in particular intact rivers are of high importance for upcoming generations.
- The worst impacts of dams, such as the disruption of river continuity for biota, the altered sediment balance (which results in channel incision and coastal erosion) and the significant changes of hydrological regimes which affect floodplains and their ecosystem services must be mitigated or prevented from the beginning.

6

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