Energy type	Levelised cost of electricity (2020 USD/kWh)		
	2010	2020	Percent change (%)
Bioenergy	0.076	0.076	0
Geothermal	0.049	0.071	45
Hydropower	0.038	0.044	18
Solar photovoltaic	0.381	0.057	-85
Concentrating solar power (CSP)	0.340	0.108	-68
Onshore wind	0.089	0.039	-56
Offshore wind	0.162	0.084	-48

Table 1: Levelised cost of electricity trends by technology, 2010 and 2020. Source: International Renewable Energy Agency (IRENA, 2021).

improvements and competitive supply chains, becoming increasingly attractive and accessible for new energy investments. Between 2010 and 2020, the global weighted-average cost of electricity from onshore wind fell by 56 %, while for solar energy the cost dropped by 85%; over the same period, the hydropower generation costs increased by 18%, surpassing the costs for onshore wind energy *(tab.1).*

Considering that hydropower energy comes with dramatic environmental costs and is losing its price attractiveness due to the current progress of other renewable energy sources, we consider that a revision of the energy policy of Romania is needed, based on current developments at the international level and state-of-the-art data and projections, not on reviving projects abandoned for decades and breaching environmental legislation.

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Dam removal: just a trend or a fast forward strategy for healthy rivers?

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The importance of river connectivity for biodiversity and ecosystem services of rivers is common knowledge today. River connectivity is perceived in four dimensions: longitudinal, lateral, vertical and temporal. Rivers are pathways not only for water, but also for sediments, organic matter and of course wildlife (Grill et al. 2019; Zeiringer et al. 2018). Rivers have been utilised by man for thousands of years and by doing so river ecology and especially the connectivity were altered in many ways. Already a few centuries ago, the apparent negative effect of barriers, especially on fish, was detected and first mitigation measures like technical fish-ways have been built. Given the enormous degree of fragmentation, the re-establishment of connectivity has become one of the main pillars of river restoration and river basin management.

While dam removal is by far not new to water management (on the contrary, historical evidence shows that construction of weirs and dams happened frequently), it still seems to be the second choice, when it comes to today's river restoration. For example, the river basin management plan for Austria (BMLRT 2021) does not mention dam removal at all, nor does the guideline for fish-passages. This is remarkable, as it is clear that dam removal is by far the most effective, and in the long-run cheapest way to deal with obstacles (BMLFUW 2017). Moreover, it is the only way to fully restore longitudinal connectivity.

There are three excellent reasons that indicate a special focus on dam removal: First of all, recent research revealed that the amount of river fragmentation has been underestimated significantly. By means of field-proofing Belletti et al. (2020) estimate, that only 50% of barriers are recorded in official databases. In total, up to 1.2 million barriers could fragment rivers in Europe. Furthermore, we would require a uniform definition of when a transverse structure is considered a (full) barrier to migration. Secondly, there is clear evidence that dam removal is also a very successful river restoration technique, which has delivered positive results in many cases (Gough et al. 2018). Finally, it is important to note that the European Commission with the new Biodiversity Strategy expressed a strong determination to restore river ecosystems by means of dam removal and floodplain reconnection (European Commission 2022).

WWF is partner of the Dam Removal Europe Initiative. In 2021, WWF presented a first analysis of reconnection potential through barrier removal for the whole of Europe (Schwarz 2021), WWF teamed up in several projects to remove barriers. Currently the authors started to compile an inventory of dam removal projects in Austria with promising first results.

River fragmentation in Europe and the Danube basin

The AMBER consortium (2020a) collected information on more than 630,000 barriers in Europe from different sources. But accurate field-proofing in pilot catchments showed, that the actual density of barriers is much higher, than official records. Taking undetected barriers into account Belletti et al. (2020) estimate that in total, up to 1.2 million barriers intersect the river continuum in Europe. Most of these barriers are less than 2 m high.

With regard to the height, it is important to note that barriers up to a height of approx. 0.3 m can usually be easily overcome by adult salmonids, but can represent an impassable obstacle for small fish species and juveniles in general. Barrier structures with a height of more than approx. 0.7 m can only be passed by single individuals that have a special physical fitness.

The transboundary river basin management plan for the river Danube (ICPDR 2021) records about 1,000 interruptions in large rivers with a catchment area spanning over 4,000 km². It is stated that the main driver for fragmentation is hydropower generation. Austria has the largest share of barriers. The total amount of barriers in the entire river network is of

Figure 1: Dam removal at the Hornbach (Tyrol). To reduce river-bed degradation and related safety risks at the Lech River, several sediment control structures - up to 16 m high - were removed in relevant tributaries. At the Hornbach, 900.000 m³ of bedload are released again step by step, contributing substantially to ecosystem functions and habitat availability. About 16 km of river-stretches are reconnected (Credit: Toni Vorauer/WWF).

course much higher. The AMBER atlas locates 45,000 dams in the Danube river basin (AMBER Consortium 2020a). Taking again into account that many dams have not been documented, it is clear that actual figures are even higher.

Austria and Germany are among the countries with the highest density of barriers with one, resp. two barriers per river kilometre. About 28,000 barriers which are unpassable for fish were identified in Austria.

Barriers fulfil different functions in Europe. Hydropower production, flood protection and irrigation are the most common purposes (EEA 2021). River regulation also necessitates transverse structures to reduce the sole gradient due to the loss of course length. However, it is remarkable that the purpose of a large quantity of dams is unclear. It is estimated that up to 100,000 barriers in Europe are even obsolete (AMBER Consortium 2020b).

From technical fish-passes to the removal of barriers

Re-establishment of connectivity is a common measure to improve the ecological status of rivers. First fish passages date back to the 18th century (Birnie-Gauvin et al. 2018). In Austria, the connectivity was improved for about 1.665 barriers between 2006-2021. According to the Danube river basin management plan along the large river stretches only one third of the barriers are equipped with fish passages (Haidvogl et al. 2021). Compared to the amount of barriers, it is obvious that the number of measures taken is extremely small. The implementation of the Water-Framework Directive is not on track and progress is delayed.

Additionally, the impact of technical mitigation measures is subject to intense discussions. Effectiveness of fish-ways is considered low (Noonan et al. 2012), fish migrating downstream still face a huge mortality risk (Radinger et al. 2021) and the alteration of ecosystem functions and effect of barriers on habitat availability is often not taken into consideration. A comparative analysis of measures clearly showed that removal of barriers is more effective and cheaper than the construction of technical fishways (BMLFUW 2017). It is clear that the difference between removing a barrier and constructing a fishway is enormous and the first question in the decision-making process should always be, whether a barrier is necessary at all (Birnie-Gauvin et al. 2018).

Accordingly, it is good news that approximately 5,000 barriers have been removed in Europe in the past decades (Dam Removal Europe 2022). France, Sweden and Finland can be seen as early adopters in terms of dam removal in Europe. Meanwhile, other countries of the Danube basin like Germany, Austria, Slovakia, Romania and Ukraine also started to contribute to the overall reduction of barriers. In Austria, 198 barriers were completely removed in recent years (BMLRT 2021). This accounts for 11.9% of all measures that target barriers. According to the datasets of the Austrian river basin management plan (BMLRT 2021)

Figure 2: *Removal of a small weir at river Maltsch (Upper Austria). The Maltsch River is protected under Natura 2000. Several obsolete small barriers interrupted the river. In 2021, the water management agency removed several dams, entirely freeing about 10 km of the river again (Credit: Sarah Höfler/blattfisch).*

mainly small dams along alpine river stretches were removed. The obstacles had served flood-protection and to a smaller amount hydropower production.

Many different examples – from gigantic hydropower plants and check-dams to small ramps - show, that removal of barriers is feasible and a powerful mean to restore rivers. In figure 1 to 3 different examples are presented. Many additional cases are available (www.damremoval.eu, https://dam-removal-goes-alps.de/start.html).

Dam removal on top of the EU restoration agenda

It is obvious that the number of barriers removed is small compared to the huge amount of existing barriers. Nevertheless, recent projects are of great importance to get removal started. Member states of the European Union now are ready to go one step further. The new Biodiversity Strategy contains clear and ambitious restoration objectives: ´It sets a target to restore at least 25,000 km of rivers into a free-flowing state, through two main types of action: removal of barriers and the restoration of floodplains and wetlands by 2030´ (European Commission 2022). The European Commission made clear, that this objective goes beyond the WFD obligation to reach good ecological status of water-bodies. The strategy refers to the concept of free-flowing rivers, which encompasses all four dimensions of river continuum. To achieve the set goal a thorough concept to identify promising river stretches and to prioritise obstacles is needed. A comprehensive study commissioned by WWF identified more than 850 barriers with high reconnection potential and more than 7,200 obstacles with good ecological preconditions for reconnection in Europe (Schwarz 2021). These barriers are qualified by a great potential to restore long free-flowing stretches, have potential for floodplain reconnection or improvement of protected areas. Of course, the dam removal concept has to be embedded in more holistic strategies for river restoration, like the concepts presented in the MEASURES project for the Danube River (Haidvogl et al. 2021). The large number of removals that are necessary to achieve the set 25,000 km target show that dam removal is key to river recovery.

To reconnect and restore rivers it is necessary to mainstream dam removal. Given the fact that hardly any free-flowing rivers are left in Europe (Grill et al. 2019), 70-90%

Figure 3: *Removal of lateral barriers at the Danube with the EU Life project Dynamic-Life-Lines-Danube (Lower Austria). In the Nationalpark Donau Auen, lateral connection of Danube side-arms was re-established by removing solid traversal structures and river embankments. This action contributes to restoration of lateral connectivity and near-natural processes (Credit: Tögel/viadonau).*

of floodplains are environmentally degraded (EEA 2021) and the fact that thousands of more dams are planned even in protected areas (Schwarz 2019), it is time to boost removal - especially of thousands of outdated or even obsolete dams.

Today it is common sense to keep our environment free of harmful waste. Abandoned dams are like waste as they harm rivers and reduce their ecosystem services. With that in mind, it should be taken for granted that dams are removed if they are not needed anymore. To do so, formal procedures have to be improved and technical and financial support must be made available.

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Danube Transnational Programme
MEASURES

Managing and restoring aquatic ecological corridors for migratory fish species in the Danube River Basin (MEASURES)

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Danube´s migratory fish species suffer from habitat change, continuum interruption and in some sections also from overfishing and poaching, respectively. All sturgeon species are particularly affected and solutions to save and restore their severely threatened or even extinct populations are urgently needed. Besides these ancient species, Danube shads and potamodromous fish are concerned, too. Transnational cooperation and national endeavors have reached important milestones such as temporary or permanent sturgeon fishing bans in most Danube countries except Slovenia, Croatia and some Austrian provinces, or the construction of fish migration aids in the Upper Danube. But still, many pressures remain.

The Interreg-funded project 'Managing and restoring aquatic Ecological corridors for migratory fish species in the Danube River Basin' (MEASURES) aimed to create ecological corridors by identifying key habitats and initiating protection measures along the Danube and its main tributaries. Sturgeons and other migratory fish species acted as flagship species in support of the project goals. MEASURES acknowledged that sturgeons and other migratory fish species represent a historical, economic and natural heritage of the Danube and are indicators of the ecological status of its watercourses, especially concerning the function of the river as an ecological corridor. Transnational management of these corridors and restoration actions, as well as restocking with indigenous species are essential.

Identification and mapping of key habitats of migratory fish species

MEASURES partners developed and tested joint methods to identify and map spawning, nursery, feeding, wintering and resting habitats of selected migratory species (Cokan et al. 2021). Diverse sources such as reports, field protocols or museum specimens were used to determine potential habitats. Further, maps, aerial and satellite images, bathymetry maps and field measurements were analyzed using ecological traits of species. The actual use of potential habitats was verified by scrutinizing the results of recent field surveys and sampling campaigns during the project. The