A critical review of best practice mitigation towards low ecological impacts from large hydropower in Europe and the US

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ABSTRACT: The international community is facing multiple crises today, including the climate crisis (IPCC, 2021), the nature crisis (IPBES, 2019), and in some regions the energy crisis (IEA, 2022). The challenges are complex and the UN has agreed on a set of sustainability goals that all countries are targeting until 2030 respectively 2050. To address these goals, the EU has created the Green Deal: a set of strategies and regulations that aims for no net greenhouse gas emissions by 2050, decoupling economic growth from resource use, and leaving no person or place left behind. This includes the Taxonomy of Sustainable Finance's Do No Significant Harm (DNSH) criteria, that is, activities addressing one or more of the six EU Taxonomy objectives must also do no significant harm to any of the other. For electricity from hydropower (HP) to qualify as sustainable, needs to meet specific criteria related to protection of biodiversity and ecosystems (by following the river continuum concept), and halt greenhouse gas emissions. In this review, based on expert judgement we compiled large-scale HP projects from Austria, Norway, Portugal, Switzerland, and the US, with a high likelihood for low ecological impact due to best practice mitigation solutions. These HP projects are selected because they have modern licenses with ambitious mitigation measures, at least regarding individual ecological impacts. Some of these projects will effectively serve as pilot sites for sustainable solutions, and be among the first of their kind in the world for supporting riverine ecosystem functions. The main objectives of this study are to i) highlight modern solutions for mitigating HP impacts, ii) compare environmental performance of new mitigation measures to current standard practice and iii) discuss if the compiled cases are all likely to meet sustainability standards. In this study we compare the level of sustainability and whether we seem to have a common understanding of the best available mitigation strategies for large-scale or complex hydropower projects. All cases have environmental flow or ramping requirements, and their complexity varies based on plant characteristics. For example, some plants may have flow requirements to mitigate hydropeaking while others will be addressing flow alterations in by-passed sections. Several of these cases have mitigated hydropeaking either by retention basins or by operational ramping restrictions, to significantly reduce stranding and flushing of riverine biota. Alternative technologies like huge batteries and optimalization algorithms are feasible solutions in some of the cases to make hydropeaking more sustainable. Other cases have been required to mitigate thermal alterations,

by installing dual lake reservoir intakes. Safe fish migration aids are implemented where relevant. An important mitigation potential in several of the cases are related to multiple stressors affecting river ecosystems, as not only flow alterations affect biota, but also habitat availability. Thus, the establishment or restoration of suitable habitats, e.g. by river widening, reconnection of tributaries or management of spawning grounds, may be needed to ensure sustainable populations of riverine biota in the HP impacted rivers.