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Materials, resources, and CO_2 impacts of building new renewable power plants to reach EU's goals of carbon neutrality

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ABSTRACT

The European Union's low carbon power plants installed capacity needs to increase by 90% by 2030. Using a spreadsheet model, we calculate the total amounts of construction materials (henceforth materials) and natural resources (henceforth resources) used for the new renewable and nuclear power plants. Considering concrete, glass, and steel as materials and sand and water as resources, future CO_2e impacts are estimated using 2010–2020 as a reference. To test if circular economy measures reduce the effects of materials and resource consumption, we derive three near-future scenarios for the decade 2020–2030: business as usual (BAU), EU manufacture (EUM), and circular (CIRC). Independent of the scenario, CO_2e emissions double from increasing low-carbon power plants. Circular economy substantially lowers resource consumption but not carbon emissions. With 90% recycling (CIRC), we spare 90% sand and 5% water compared to a BAU scenario. Resource-efficient power plant design and major technological advancement in recycling processes are needed to fulfill a CIRC scenario.

1. Introduction

The current policy landscape in the European Union (EU) aims to achieve carbon neutrality by 2050 in order to comply with the 1.5 °C temperature increase target in the Paris Agreement (IPCC, 2021). Overall, the EU Green Deal aims to secure and make the EU energy supply affordable, particularly by developing a power sector based mainly on renewable energy sources (RES) (European Commission, 2022). For the year 2030, the EU had, until recently, a greenhouse gas emission (GHG) mitigation target of a 40% reduction from 1990's levels. This was recently upgraded to 55% leading to the Fit for 55 (henceforth FF55) package. The FF55 proposes a set of reviews and updates of current legislation to bring online this stricter mitigation target (European Commission, 2022). This pressurizes the reduction of fossil-fuel dependency and acceleration of the demand for RES power plants installed capacity, consequently increasing the demand for construction of new infrastructure to support new RES power plants – and for this, we will need a large amount of construction materials. The one caveat is that construction materials are among the most environmentally costly materials we consume daily (Churkina et al., 2020; European Environment Agency, 2021a) and the primary source of GHG emissions worldwide (Hertwich, 2021).

Steel, concrete (cement), and glass are among the most carbon- and resource-intensive (e.g., sand and water) construction materials (Andrew, 2019a; Churkina et al., 2020a; Hertwich, 2021a).

- 1860 million tonnes (Mt) of steel production emitted 2.6 Gt CO_2/yr globally in 2020 (WorldSteel, 2021);
- 10 billion m^3 of concrete (3.8 Gt of cement) emitted between 1.50 (Andrew, 2019a) and 2.6 Gt CO_2/yr in 2012 (Hertwich, 2021; Miller et al., 2016); and
- Glass manufacturing produced at least 0.42 Gt CO_2/yr (Hertwich, 2021).

Although there is extensive work on embodied carbon in construction materials – especially in buildings (Amiri et al., 2021; Ibn-Mohammed et al., 2013; Ng et al., 2022) – these estimations are insipient for other types of structures, like low-carbon power plants. RES power plants need: (i) Concrete and steel to create the foundations of onshore and offshore wind power, the foundations of solar photovoltaic (PV) and concentrated solar power (CSP) panels, and the entire infrastructure of hydropower dams and nuclear power plants; (ii) steel as the primary

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