Enhanced Weathering (EW) and Ocean Alkalisation

Weathering is the natural process of rock decomposition via chemical and physical processes in which CO₂ is spontaneously consumed and converted to solid or dissolved alkaline bicarbonates and/or carbonates (IPCC 2005). The process is controlled by temperature, reactive surface area, interactions with biota and, in particular, water solution composition. CDR can be achieved by accelerating mineral weathering through the distribution of ground-up rock material over land (Hartmann and Kempe, 2008; Wilson et al., 2009; Köhler et al., 2010; Renforth, 2012; ten Berge et al., 2012; Manning and Renforth, 2013; Taylor et al., 2016), shorelines (Hangx and Spiers, 2009; Montserrat et al., 2017) or the open ocean (House et al., 2007; Harvey, 2008; Köhler et al., 2013; Hauck et al., 2016). Ocean alkalisation adds alkalinity to marine areas to locally increase the CO₂ buffering capacity of the ocean (González and Ilyina, 2016; Renforth and Henderson, 2017).

In the case of land application of ground minerals, the estimated CDR potential range is 0.72–95 GtCO₂ yr⁻¹ (Hartmann and Kempe, 2008; Köhler et al., 2010; Hartmann et al., 2013; Taylor et al., 2016; Strfeler et al., 2018) (low evidence, low agreement). Marine application of ground minerals is limited by feasible rates of mineral extraction, grinding and delivery, with estimates of 1–6 GtCO₂ yr⁻¹ (Köhler et al., 2013; Hauck et al., 2016; Renforth and Henderson, 2017) (low evidence, low agreement). Agreement is low due to a variety of assumptions and unknown parameter ranges in the applied modelling procedures that would need to be verified by field experiments (Fuss et al., 2018). As with other CDR options, scaling and maturity are challenges, with deployment at scale potentially requiring decades (NRC, 2015a), considerable costs in transport and disposal (Hangx and Spiers, 2009; Strfeler et al., 2018) and mining (NRC, 2015a; Strfeler et al., 2018).

Site-specific cost estimates vary depending on the chosen technology for rock grinding – an energy-intensive process (Köhler et al., 2013; Hauck et al., 2016) – material transport and rock source (Renforth, 2012; Hartmann et al., 2013), ranging from 15–40 USD tCO₂⁻¹ to 3,460 USD tCO₂⁻¹ (Schuiling and Krijgsman, 2006; Köhler et al., 2010; Taylor et al., 2016, limited evidence, low agreement; Figure 4.2). The evidence base for costs of ocean alkalisation and marine enhanced weathering is sparser than the land applications. The ocean alkalisation potential is assessed to be 0.1–10 GtCO₂ yr⁻¹ with costs of 14–>500 USD tCO₂⁻¹ (Renforth and Henderson, 2017).

The main side effects of terrestrial EW are an increase in water pH (Taylor et al., 2016), the release of heavy metals like Ni and Cr, and plant nutrients like K, Ca, Mg, P and Si (Hartmann et al., 2013), and changes in hydrological soil properties. Respirable particle sizes, though resulting in higher potentials, can have impacts on health (Schuiling and Krijgsman, 2006; Taylor et al., 2016); utilisation of wave-assisted decomposition through deployment on coasts could avert the need for fine grinding (Hangx and Spiers, 2009; Schuiling and de Boer, 2010). Side effects of marine EW and ocean alkalisation are the potential release of heavy metals like Ni and Cr (Montserrat et al., 2017). Increasing ocean alkalinity helps counter ocean acidification (Albright et al., 2016; Feng et al., 2016). Ocean alkalisation could affect ocean biogeochemical functioning (González and Ilyina, 2016). A further caveat of relates to saturation state and the potential to trigger spontaneous carbonate precipitation. While the geochemical potential to remove and store CO₂ is quite large, limited evidence on the preceding topics makes it difficult to assess the true capacity, net benefits and desirability of EW and ocean alkalinity addition in the context of CDR.

5 Other pyrolysis products that can achieve net CO₂ removals are bio-oil (pumped into geological storages) and permanent-pyrolygas (capture and storage of CO₂ from gas combustion) (Werner et al., 2018).