THE ROLE OF BECCS TO DELIVER NEGATIVE CO_2 EMISSIONS IN EUROPE

Lorenzo Rosa[1*], Daniel Sanchez[2], Marco Mazzotti[1]
[1] Institute of Energy and Process Engineering, ETH Zurich, 8092 Zurich, Switzerland
[2] Department of Environmental Science, Policy, and Management, University of California, Berkeley, United States of America

* Corresponding author e-mail: lorosa@ethz.ch

Abstract

Bio-Energy with Carbon Capture and Storage (BECCS) is a key climate mitigation technology, which involves the capture and permanent sequestration of biogenic carbon dioxide (CO_2). To reach net-zero-CO_2-emissions by 2050, it is forecasted that many million tons of CO_2 will have to be sequestered through BECCS in Europe. There are different industrial processes that utilize biomass for bio-energy production, namely, pulp and paper mills, biogas facilities, incinerators, and biomass-fired power plants. Moreover, crop residues, organic food waste, and livestock manure could be utilized to transform biomass from a poor energy carrier to an efficient carbon drawdown carrier through BECCS. Here, we quantify the techno-environmental potential for biogenic carbon dioxide removal considering prospective BECCS opportunities that do not require purpose-grown bio-energy plantations. Combining process engineering with a bottom-up assessment, we find that there are 200 million tons CO_2 yr^{-1} that could be deployed for biogenic carbon dioxide removal through BECCS in Europe. We find that this biogenic CDR potential is equivalent to 5% of 2018 total European greenhouse gas emissions. We find that 62 million tons of biogenic CO_2 yr^{-1} are located within a distance of 300 km to prospective CO_2 storage sites, and therefore do not require long-distance CO_2 source-sink transport networks. We then determine to what extent the adoption of BECCS would allow to mitigate hard-to-abate emissions. We show that most European countries will not be able to reach climate-neutrality with domestic BECCS endowments and will likely need to resort to other CDR strategies and outsource biomass from other countries. Country-specific BECCS potential are still unknown and the proposed research has the potential to help decision makers to design suitable and appropriate climate policies. Because policy makers are investigating pathways to reach net-zero targets by 2050, the results of this proposed work could help to estimate the role that BECCS could have to reach net-zero targets by 2050.

Keywords: *BECCS; Net-zero Emissions; Negative Emission Technologies.*

1. Introduction

Atmospheric carbon dioxide removal (CDR) will likely play a critical role in climate mitigation and in reaching net-zero carbon emissions worldwide[1-8]. CDR schemes, or negative emissions technologies (NET), are strategies whereby CO_2 is captured and removed from the atmosphere[9-16]. CDR strategies are receiving an increasing interest not only from the scientific community, but also from the international political community and the corporate world. For example, CDR is being considered by European countries to mitigate hard-to-abate carbon emissions and to reach net-zero-CO_2-emissions by 2050. Scenarios for CDR deployment consistent with climate goals involve gigatonne-scale deployment of Bio-Energy with Carbon Capture and Storage (BECCS) within the next decades[17,18]. BECCS involves the capture and permanent sequestration of biogenic CO_2 produced during energy conversion from biomass[13,14] and is widely considered due to its near-term feasibility, scalability, and ability to produce reliable bio-energy[14,15].

Creating vast bioenergy plantations could jeopardize food production, exacerbate water scarcity and have negative impacts on biodiversity and rural livelihood[19-22]. Technology developers and policymakers should ensure that BECCS operations reliably sequester CO_2 emissions and minimize unnecessary environmental impacts. There are different industrial processes that could avoid new bioenergy plantations and provide opportunities for CDR through BECCS, namely, pulp and paper mills, incinerators, wastewater treatment facilities, and biomass co-fired power plants[23-29]. Biogenic CDR could also be performed during biogas production from crop residues and household organic food waste[24,25,30]. Moreover, biogenic CDR could be deployed by retrofitting biogas facilities currently treating livestock manure[24, 30].

2. Methods

In this study, we combine process engineering, with a bottom-up assessment to determine the techno-environmental potential of biogenic CDR in Europe considering prominent BECCS schemes. Specifically, we assessed the techno-environmental potential for biogenic CDR (10^6 tons CO_2 yr^{-1}) at 1 km resolution for 30 European countries (European Union countries, Switzerland, the United Kingdom, and Norway) considering different BECCS schemes (Figure 1).

For each BECCS scheme, biogenic CDR was assessed considering already existing point sources and distributed potential sources of biogenic CO_2.

We then designed BECCS supply chains for seven prominent sources for biogenic CDR considering bio-energy sources that would not require additional pressures on land and water resources through purpose grown bio-energy plantations. Using a bottom-up assessment, biogenic CDR was assessed considering already existing point sources and distributed potential sources of biogenic CO_2. For already existing point sources we considered: 1) pulp and paper mills; 2) waste-to-energy plants (or incinerators); 3) biomass co-fired power stations (or bio-power); and 4) urban wastewater treatment plants. For distributed potential sources we designed three BECCS schemes that could be potentially deployed to produce methane from 5) current crop residues and 6) currently collected household organic food waste; and produce methane from 7) collectible livestock manure.

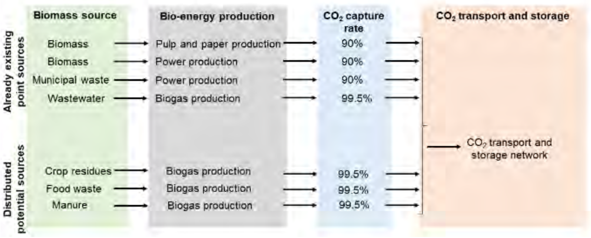

Figure 1: BECCS technology chains for seven prominent sources for biogenic CDR.

3. Results

Full results of this study are available at Rosa et al., 2021[31]. We find that there are 201 Mtons of biogenic CO_2 that could be deployed for CDR in Europe (Figure 2). We estimate that 65% of biogenic CDR potential is from existing point sources (pulp and paper mills, incinerators, bio-power plants, and wastewater treatment facilities), and 35% is from potential BECCS distributed sources (crop residues, food waste, and livestock manure). With 62 Mtons CO_2 yr^{-1}, pulp and paper facilities have the greatest potential for biogenic CDR from existing point sources, followed by waste-to-energy facilities (36 Mtons CO_2 yr^{-1}), biomass co-fired plants (31 Mtons CO_2 yr^{-1}), and wastewater treatment plants (1 Mtons CO_2 yr^{-1}) (Figure 3). Considering distributed potential biogenic BECCS sources, crop residues have the greatest potential for biogenic CDR (36 Mtons CO_2 yr^{-1}), followed by livestock manure (19 Mtons CO_2 yr^{-1}), and household organic food waste (18 Mtons CO_2 yr^{-1}) (Figure 2). Sweden, with 31 Mtons CO2 per year, has the largest biogenic CDR potential among European countries, followed by Germany (28 Mtons CO2 per year), the United Kingdom (24 Mtons CO2 per year), Finland (23 Mtons CO2 per year), and France (22 Mtons CO2 per year).

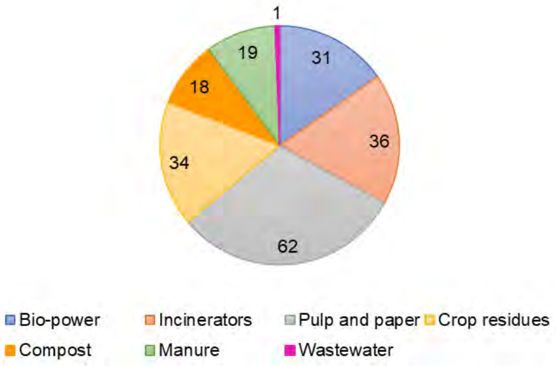

Figure 2: BECCS-specific biogenic CDR potentials in Europe (10^6 tons CO_2 per year).

Assuming that 5% of 2018 emissions will need to be removed through CDR, we find that Europe has sufficient domestic BECCS potential to mitigate hard-to-abate emissions. However, under a low emissions reduction scenario (or 30% CDR), we find that Europe could only meet 16% of the CDR necessary to reach net-zero emissions with domestic BECCS resources. Some countries are better positioned to reach net-zero emissions with domestic BECCS endowments than others (Figure 3). In fact, we find that Sweden, Estonia, and Finland will be able to mitigate 5% and 30% of their emissions with domestic BECCS resources (Figure 3). Because of their large endowments, Switzerland, Portugal, and Austria could mitigate 5% of their 2018 emissions by sequestering biogenic CO_2 from already existing point sources (Figure 5b). By deploying full biogenic CDR from BECCS endowments, Germany, the United Kingdom, France, and Spain will be able to mitigate 5% of their emissions.

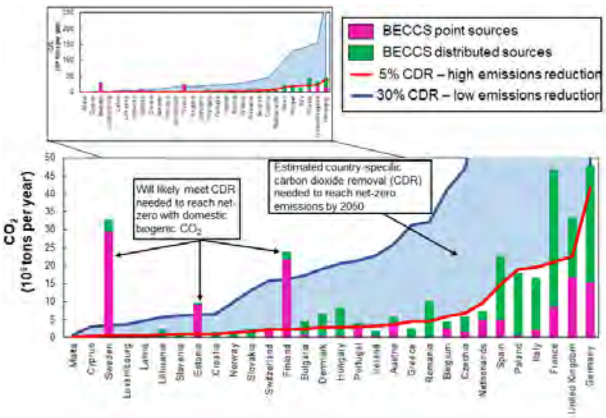

Figure 3. Comparison between domestic BECCS endowments and country-specific CDR quotas needed to reach net-zero emissions by 2050. Country-specific CDR quotas are assessed assuming that 5% to 30% of current total greenhouse gas emissions will need to be balanced with CDR to reach net-zero emissions by 2050.

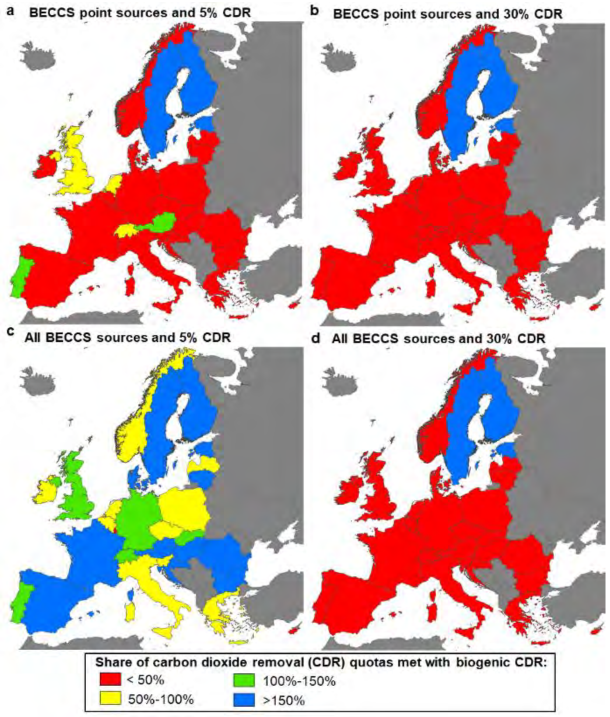

Figure 4. Map showing the share of CDR quotas that could be potentially met with domestic BECCS endowments. We considered four scenarios considering a combination among low emissions reduction (30% CDR), high emissions reduction (5% CDR), low BECCS adoption from biogenic point sources only, and high BECCS adoption from full deployment of domestic BECCS endowments.

By investigating BECCS potentials, this work may guide to identify the role of BECCS to deliver negative emissions through biogenic carbon dioxide removal in Europe.

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