International Journal of Greenhouse Gas Control 40 (2015) 401–430

Contents lists available at ScienceDirect

International Journal of Greenhouse Gas Control

journal homepage: www.elsevier.com/locate/ijggc

Biomass and carbon dioxide capture and storage: A review

Jasmin Kemper

IEA Greenhouse Gas R&D Programme (IEAGHG), Pure Offices, Cheltenham Office Park, Hatherley Lane, Cheltenham, Gloucestershire, GL51 6SH, UK

ARTICLE INFO

Article history:
Received 24 April 2015
Received in revised form 11 June 2015
Accepted 13 June 2015
Available online 5 August 2015

Keywords:
Biomass
bioenergy
Bio-CCS
BECCS
negative emissions
land use change
nexus

ABSTRACT

This paper provides an overview of biomass with carbon capture and storage (Bio-CCS or BECCS) at the systems level. It summarises the relevant information from the recent 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), describes the progress made since earlier reports and considers additional results recently published in literature. The focus is hereby not on the technical challenges but rather on the surrounding sustainability issues.

Bio-CCS shows significant potential to achieve net CO_2 removal from the atmosphere at a cost that is comparable to conventional CCS technologies. However, uncertainties remain due to the little experience with large-scale Bio-CCS demonstration plants, gaps in climate policies and accounting frameworks, missing financial instruments, unclear public acceptance and complex sustainability issues. A major conclusion is that the deployment of Bio-CCS cannot take place in isolation, thus will require an approach addressing the inextricable links within the food-water-energy-climate nexus.

1. Introduction

The 5th Assessment Report (AR5) of Working Group III (WGIII) of the Intergovernmental Panel on Climate Change (IPCC) emphasises that large-scale changes in global and national energy systems during the coming decades will be essential to reduce atmospheric CO_2 levels (IPCC, 2014a). In this context, deep-reduction scenarios, i.e. those achieving below 450 ppm by 2100, will require far-reaching improvements in energy efficiency as well as an extensive rollout of zero- or low-carbon energy supply by 2050 (Clarke et al., 2014). Options for achieving timely decarbonisation of the energy sector are the deployment of renewable energy (RE), nuclear power, carbon capture and storage from fossil energy (Fossil-CCS) and negative emissions technologies (NETs), also referred to as carbon dioxide removal (CDR). AR5 contains a large set of new scenarios compared to the 4th Assessment Report (AR4) in 2007 (IPCC, 2007).

Carbon capture and storage (CCS) describes a process that separates a relatively pure stream of CO_2 from industrial or power plants and, after conditioning and compression, stores it in suitable geological formations (IPCC, 2014b). The term mostly refers to application of the process to fossil energy, i.e. coal- or gas-fired power plants.

NETs and CDR are means to remove CO_2 from the atmosphere by either increasing natural carbon sinks or using chemical engineering. NETs/CDR lead to a net removal of CO_2 from the atmosphere, whereas Fossil-CCS generally only decreases the rate at which CO_2 is added, at best to nearly zero. It is possible to use the terms NET and CDR interchangeably (McGlashan et al., 2012a; McLaren, 2012; Tavoni et al., 2012). For reasons of consistency, this paper will only use the term NET. AR5 notes that some NETs fall under the category of geoengineering depending on their magnitude, scale and impact. In addition, the differentiation between NETs and mitigation is not clear at all times due to partially overlapping definitions. Examples for NETs are iron fertilization, large-scale afforestation, direct air capture (and sequestration) (DAC(S)), and biomass in combination with CCS (Bio-CCS or BECCS).

Throughout the literature, the terminology and definition of Bio-CCS is not fully consistent. The IPCC's Special Report on Carbon Dioxide Capture and Storage (SRCCS) in 2005 merely described "biomass-based CCS" as "CCS in which the feedstock is biomass" (IPCC, 2005).

The Bio-CCS Joint Taskforce (JTF), brought into life by the European Biofuels Technology Platform (EBTP) and the Zero Emissions Platform (ZEP), defines Bio-CCS as (ZEP and EBTP, 2012):

> "[...] processes in which CO_2 originating from biomass is captured and stored. These can be energy production processes or any other industrial processes with CO_2-rich process streams originating from biomass feedstocks. The CO_2 is separated from these processes with technologies generally associated with CCS for fossil fuels. Biomass binds carbon from the atmosphere as it grows; but with the conversion of the biomass, this carbon is again released as CO_2. If, instead, it is captured, transported to a storage site and permanently stored deep

E-mail address: jasmin.kemper@ieaghg.org

http://dx.doi.org/10.1016/j.ijggc.2015.06.012