Energy Policy 104 (2017) 89–99

Contents lists available at ScienceDirect

Energy Policy

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

Socio-political prioritization of bioenergy with carbon capture and storage

Mathias Fridahl

Centre for Climate Science and Policy Research (CSPR), Department of Thematic Studies – Environmental Change, Linköping University, 581 83, Linköping, Sweden

ARTICLE INFO

Keywords:
Bioenergy with carbon capture and storage (BECCS)
Electricity supply
Transition management
Transformational change
UNFCCC

ABSTRACT

Limiting global warming to well below 2 °C requires the transformation of the global energy system at a scale unprecedented since the industrial revolution. To meet this 2 °C goal, 87% of integrated assessment models opt for using bioenergy with carbon capture and storage (BECCS). Without BECCS, the models predict that the goal will be either unachievable or substantially more costly to meet. While the modeling literature is extensive, studies of how key climate policy actors perceive and prioritize BECCS are sparse. This article provides a unique intercontinental mapping of the prioritization of BECCS for the long term transition of the electricity supply sector. Based on survey responses from 711 UN climate change conference delegates, the article reports the low prioritization of BECCS relative to alternative technologies, indicating an urgent need for studies of the socio-political preconditions for large-scale BECCS deployment.

1. Introduction

The UN Framework Convention on Climate Change (UNFCCC) has set an ambitious goal for world politics in the twenty-first century: to hold the average global temperature increase at the end of the century to well below 2 °C relative to pre-industrial levels (UNFCCC, 2016). With current human-induced warming of roughly .85 °C, approximately 3.9 billion people in energy poverty, and a high likelihood that world population will continue to grow throughout this century, meeting energy demand while radically reducing emissions requires societal transformation at scales unprecedented since the industrial revolution (Gerland et al., 2014; González-Eguino, 2015; IPCC, 2014).

In this context, the combination of carbon capture and storage (CCS) technologies with energy production from biomass – so-called BECCS – is proposed as a promising mitigation technology for supplying energy or goods to end users while removing carbon dioxide (CO_2) from the atmosphere. The logic is simple: as plants grow they encapsulate atmospheric CO_2 in biomass that is harvested and used to produce, for example, electricity, heat, biofuels, and pulp/paper. Instead of allowing the CO_2 to recirculate into the atmosphere, it is captured, transported, and deposited in long-term geological storage sites (IPCC, 2014).

In theory, if harvested biomass is regrown, BECCS can achieve anything from reduced global emissions to net-negative emissions (Gough and Upham, 2011). The highest potential is identified in the electricity sector (IEA, 2011b; Tokimatsu et al., 2016). Furthermore, of all scenarios associated with a high (i.e. 66%) likelihood of achieving the 2 °C goal, 87% include large-scale BECCS deployment (Fuss et al., 2014).

While many models try to address technical and economic uncertainties through parameterization or by incorporating, for example, explicit land use modeling components, models often fail to address non-technical uncertainties related to, for example, politics and governance. Given that the technical and economic uncertainties are high enough to call into question the scale at which BECCS is applied in the models (Kemper, 2015), the fact that very little is known of the legitimacy aspects of BECCS is daunting (Dowd et al., 2015). Deploying BECCS at the scales suggested by the models will probably require government involvement, for example, by regulating markets to establish a sufficient carbon price that incentivizes deployment, by potential R & D investments, and by subsidizing negative emissions. Carbon taxes, which do not distinguish the origin of CO_2 emissions (i.e. fossil or biotic), have been evaluated to be more efficient drivers of both fossil CCS and BECCS deployment than, for example, taxes on fossil fuels. To further incentivize BECCS, a CO_2 tax could be combined with instruments that also reward negative emissions, such as subsidies (Ricci, 2012; Vergragt et al., 2011; Zheng and Xu, 2014). It is also at least somewhat possible to incentivize BECCS by generating tradable credits based on negative emissions in emissions trading systems and by being allowed to account for negative emissions from BECCS to comply with commitments under the UNFCCC (Carbo et al., 2011; Grönkvist et al., 2006).

Governments as well as non-governmental actors are therefore potentially of great importance for the future of BECCS, especially if

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E-mail address: mathias.fridahl@liu.se.

http://dx.doi.org/10.1016/j.enpol.2017.01.050
Received 4 August 2016; Received in revised form 23 January 2017; Accepted 27 January 2017

existing market drivers are too weak. Despite this, international comparative studies of how BECCS is prioritized by governments and civil society in different world regions are nonexistent. This article therefore asks:

- How is BECCS prioritized, compared with other technologies, for the long-term transition of electricity supply systems toward low-carbon configurations?
- Do priorities in different world regions correlate with the regions' technical potential for BECCS?
- Do priorities for BECCS differ among actor types?

Through addressing these questions, the article provides a preliminary international comparison of certain proxies for understanding the legitimacy of BECCS. The article focuses on the role of BECCS in the transition of national electricity supply systems, the sector with the highest technical potential for BECCS. Given that awareness of CCS and BECCS is generally low among the public (Ashworth et al., 2013; Dowd et al., 2015), the article targets actors actively involved in climate policy making by assessing survey responses from 711 UN Climate Change Conference delegates regarding technology preferences for investments in the long-term (i.e. 25–50 years) transition of electricity generation. Section two reviews current research into BECCS. Section three presents the data collection method and how the data are broken down by region and actor type. Section four highlights the main results, indicating that preferences for BECCS differ depending on the respondents' regional origins and actor types and that regional preferences correlate with regional technical potential for BECCS. Section five discusses the results in light of the current literature on BECCS. Section six concludes the article, demonstrating that BECCS has a low priority relative to other technology options, which in turn indicates an urgent need to improve our understanding of the legitimacy of BECCS.

2. Bioenergy with carbon capture and storage (BECCS)

The literature outlines several technologies for separating and capturing CO_2 from fossil and biomass fuels, all of which are associated with high costs and energy penalties (IEA, 2014; Leung et al., 2014). Although CCS can be used at any point source, it is more economically feasible at large- than small-scale sources (Wennersten et al., 2014). Storage of CO_2 has been piloted and demonstrated, incentivized by enhanced oil recovery and by carbon taxes in combination with regulations governing the maximum CO_2 content of natural gas,[1] but other forms of geological storage are also being researched and demonstrated (IPCC, 2005; Kemper, 2015). In relation to biomass use, CCS potential is highest in electricity and heat production, but pulp/paper and biofuel production may also be eligible (Carbo et al., 2011; Gough and Upham, 2011; Klein et al., 2011; Vergragt et al., 2011). To date, however, low carbon prices have made BECCS uncommercial. A schematic of the most commonly discussed components of BECCS technology systems is provided in Fig. 1.

2.1. BECCS and integrated assessment modeling

BECCS contributes significantly to most model runs associated with the IPCC Representative Concentration Pathway (RCP) 2.6. Under RCP 2.6, temperature increase above 2 °C by the end of the century relative to the 1850–1900 average is unlikely (Clarke et al., 2014). In 2100, RCP 2.6 corresponds to 421 ppm of CO_2 in the atmosphere, with preindustrial levels of approximately 280 ppm and current levels of approximately 400 ppm. As the global annual increase in atmospheric CO_2 concentration has been roughly 2 ppm/year over the last decade, it is increasingly clear that stabilizing concentrations at the levels estimated to be required to keep the global mean surface temperature increase below 2 °C will require the large-scale decarbonization of the global energy system. Furthermore, most of the increase in radiative forcing since 1750 can be attributed to the increase in the atmospheric concentration of CO_2 (IPCC, 2013).

Fully 87% of all scenarios (n=116) consistent with RCP 2.6 in the IPCC's Fifth Assessment Report require global net negative emissions in the 2050–2100 period (Fuss et al., 2014). This is achieved when "the negative emissions associated with BECCS are greater than total emissions from *all* other sources" (Gough and Vaughan, 2015: 7). Given that BECCS is currently only entering the demonstration phase, these are astonishing requirements.

The attraction of BECCS is its theoretically relatively high potential to generate global net-negative emissions that allow a temporary overshoot of CO_2 concentrations in the atmosphere, above 420 ppm, in the first half of the twenty-first century (Azar et al., 2013). If BECCS is excluded from the options of the models, the goal is out of reach or can only be achieved at substantially higher costs (Azar et al., 2010, 2013; Selosse and Ricci, 2014).

2.2. Key uncertainties contextualizing assessments of BECCS' techno-economic potential

Several uncertainties are listed in the literature as contextualizing assessments of both the technical and economic potential of BECCS. A first set of uncertainties relates to sustainable biomass production and climate dynamics. The modeled role of BECCS depends on both the future availability and price of biomass, both of which are highly uncertain. Estimates of biomass availability and pricing are driven by the relative weights assigned to competition for land for other purposes (e.g. biological diversity and food production), water, and fertilizers (Azar, 2011; Gough and Upham, 2011; Popp et al., 2014; Williamson, 2016). The unknown impact of climate change on biomass availability as well as nonlinearities in terrestrial and ocean uptake of carbon exacerbates uncertainties (Azar et al., 2013; Fuss et al., 2014). Finally, biomass production on land with high carbon stocks as well as potential indirect emissions from, for example, deforestation undermine the negative emission potential (Azar, 2011).

Second, knowledge gaps concerning available storage capacity and risks introduce further uncertainties. Estimates of the global storage capacity range from 100 to 10,000 $GtCO_2$, with outliers up to 200,000 $GtCO_2$ (Ansolobehere et al., 2007; Bradshaw et al., 2007; Humpenöder et al., 2014; IPCC, 2005; Selosse and Ricci, 2014). Potential long-term physical leakage[2] from storage is another uncertainty. Storage has traditionally been piloted in combination with enhanced oil or coal bed methane recovery, but examples of storage for mitigation purposes exist as well, driven primarily by a tax on CO_2 (IEA, 2014; Karimi et al., 2012). Natural sites of CO_2 and pilot projects have displayed low leakage, yet for mitigation purposes, storage needs to be assured on timescales different from those of enhanced oil or gas recovery (Jenkins et al., 2012). Issues of insurance and responsibilities related to, for example, monitoring and accidents triggered by unforeseen events (e.g. earthquakes) also require attention (IPCC, 2005; Zoback and Gorelick, 2012).

Third, little is known of the economies of scale related to BECCS. While BECCS can benefit from economies of scale in capital costs, large-scale operational units also incur diseconomies of scale in biomass supply and transportation. In cases in which biomass availability and geological storage capacity are co-located, transportation

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[1] For an example of a CCS demonstration project incentivized by a CO_2 tax in combination with market standards for the CO_2 content of natural gas, see the Norwegian Sleipner West gas field (Karimi et al., 2012).

[2] Physical leakage is distinct from the concept of international leakage, which refers to increases in global emissions as an effect of domestic mitigation actions. For example, if demand for fossil fuels decreases in one part of the global energy system, global prices of fossil fuels could fall, leading to increased consumption in other parts of the system.