IEA Bioenergy
Technology Collaboration Programme

Deployment of bio-CCS: case study on bio-combined heat and power

HOFOR Amager CHP, Copenhagen, Denmark

Contribution of IEA Bioenergy Task 40 to the inter-task project *Deployment of bio-CCUS value chains*

May 2021

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May 2021

Published by IEA Bioenergy

Preface

Substantial amounts of negative emissions may be required if global climate change is to be limited to well-below 2°C above pre-industrial levels, as is the ambition of the 2015 Paris Climate Agreement. Among the different negative emissions options available, bioenergy with carbon capture and storage, also referred to as bio-CCS or BECCS, is arguably one of the most commonly discussed in climate policy debates.

Up until recently, bio-CCS was primarily discussed in terms of its potential and drawbacks over very long timeframes, e.g., 2050 and beyond, but there is now growing focus on more near-term aspects. The IEA Bioenergy inter-task project *Deployment of BECCS/U value chains* runs 2019-2021 and strives to provide insights about the opportunities and challenges pertaining to taking BECCS from pilots to full-scale projects. To this end, the project puts focus not only on technological aspects but also on how BECCS business models could be set up and the role that public policy could play in enabling sustainable deployment of BECCS. Focus in the project is on the CO_2 capture, transportation and storage phases of the supply chain. Upstream biomass feedstock supply systems are only touched upon very briefly, as these issues are analyzed to great detail in other IEA Bioenergy work.

An important characteristic of BECCS is that it can be implemented in a broad range of sectors - basically any setting where there are biogenic emissions of CO_2 available in sizeable quantities. This includes generation of heat and power in various contexts, but also industrial facilities like cement production, pulp & paper mills or ethanol plants. The specifics related to BECCS implementation can however vary quite substantially from sector to sector. This is partly because of differences in technological factors like CO_2 concentrations, but also a result of how different sectors operate under widely varying commercial and regulatory conditions.

This case study is part of a series of studies carried out under the *Deployment of BECCS/U Value Chains* project with the aim to highlight these sector-specific characteristics. The case studies provide deeper insights into the key aspects that come into play for companies that are in the process of setting up value chains for capture, transportation and sequestration or utilization of biogenic CO_2.

Summary

Increased diffusion and expansion of biomass-based combined heat and power (CHP) in district heating systems has in the last decades been an important component in the phase-out of fossil fuels from space heating in several countries around the Baltic Sea. CHP enables a combination of decentralized electricity generation with recovery of heat for distribution across urban environments to homes and commercial buildings alike.

With the growing interest in negative emissions as a climate change mitigation tool, several utilities operating CHP systems in the Baltic Sea region are investigating opportunities such as adding carbon capture and utilization/storage, CCUS, to its facilities. In this case study, we present the bio-CCUS ambitions of HOFOR, which operates CHP systems in Copenhagen, Denmark.

HOFOR is owned by the City of Copenhagen, which has set a target for itself to be a carbon-neutral city by 2025, with bio-CCS being explored as one tool to achieve this. The city is about to initiate pilot trials into deploying CCS at one of its waste-to-energy (WtE) facilities. The WtE plant is located right next to the site hosting HOFORs CHP operations, and HOFOR has also started to investigate options for CCS deployment.

Even though HOFOR is still only in an early, fact-finding phase of its bio-CCUS venture, the company is fairly confident that technological challenges pertaining to deployment of the CO_2 capture component of the value chain should be manageable. However, other questions remain. One such pertains to integration of the heat requirement for the capture systems into its heat & electricity production regime and if/how there can be synergies between HOFOR's CCS project and other similar initiatives in the region. Another question is the fate of the captured CO_2 and whether this will be permanently stored or utilized in the production of e.g., transport fuels. This could be one pathway to generate revenue to cover the extra cost of the investment and operational cost of the CO_2 capture system, though policy incentives connected to national Danish mitigation targets could come into play as well.

Acknowledgments

We want to thank HOFOR for providing valuable information for this case study.

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1 Introduction

1.1 BIOMASS-BASED CHP AND CCS

Combined heat and power (CHP) systems combine electricity generation with the production of heat for district heating (DH): residual energy from electricity generation is used to heat water which is circulated in city-wide pipeline networks to provide heating for homes, industries and offices. The combination of recovery enables very high utilization of the energy content in the fuel, with more than 90% of the fuel content converted into useful energy. In many cities in the Nordic region, expansion of biomass-based CHP has enabled the phase-out of fossil fuels from space heating while the local siting means that the CHP plant also plays an important role as a decentralized source of power generation. In particular, as the production of the power output from a CHP plant correlates with the winter-peaking load curves in the Nordic region, CHP is a valuable resource for the power grid as well.

CHP can be combined with any form of fuel source – solid, gaseous or even nuclear – but the dominant type of fuel in the Nordic region tends to be different forms of wood-based biomass based on residues and by-products from forestry operations and forest industries around the Baltic Sea. At the time of writing (early 2021), there are several ongoing projects aimed at investigating the feasibility of implementing carbon capture and storage (CCS) at existing bio-CHP plants to enable bio-CCS (see e.g., Bergström 2020; Stockholm Exergi 2020), thereby adding carbon dioxide removal to the portfolio of services offered by bio-CHP systems.

In this case study, we give a more detailed presentation of one such project, based around the facilities operated by HOFOR in Copenhagen, the capital of Denmark.

1.2 THE CCS PROJECT AT HOFOR COPENHAGEN: BACKGROUND

HOFOR (short for *Hovedstadsområdets Forsyningsselskab*, approx. "Greater Copenhagen Utility") is a not-for-profit utility, owned by 8 municipalities in the Greater Copenhagen area. It is Denmark's largest utility, with more than 1,300 employees and roughly one million customers. HOFOR has total fixed assets valued at roughly €3.7 billion, and an annual net turnover of €730 million. Water and wastewater activities are owned by 8 municipalities, while energy production, district heating and cooling, and town gas are owned solely by the City of Copenhagen.

In December of 2019, the Danish parliament passed a law stating that relative to 1990 emissions, Denmark must reduce its greenhouse gasses by 70% in 2030. This is an ambitious target, and there is a general consensus amongst actors (including the Danish council on Climate Change, and Danish Energy) that it will be difficult to achieve without utilising CCS at some of the Danish biomass-based power plants (Tornbjerg, 2020). At a more local level, the city of Copenhagen has set a goal of being carbon neutral by 2025 and is therefore exploring opportunities for CCS projects at facilities owned by the city. This has led to an analysis of carbon capture at Amager Resource Center (ARC), a waste-to-energy facility jointly owned by the city of Copenhagen and four other municipalities. A carbon capture pilot project for the ARC plant will commence construction in 2021, with the plan to start capturing 12 tonnes of CO_2 per day by the end of the same year[1]. If the pilot project becomes a success, the next phase would involve implementation of a full-scale capture project at ARC that could capture 95% of CO_2 emissions in 2025 (Wittrup, 2020). In addition to this, HOFOR has begun investigations into implementation of CCS at its biomass-fired CHP plant, the focus of this case study.

[1] Another case study in this series is focused on the implementation of CCS in a waste-to-energy CHP in Oslo, Norway (Becidan 2021).

2 Project specifications

2.1 PLANT FACTS AND CO2 CAPTURE

As a not-for-profit utility, HOFOR is regulated by law, and its revenues and expenditures must balance over time. One of HOFOR's primary clients is the Metropolitan Copenhagen Heating Transmission company (CTR), which is comprised of 5 municipalities, and supplies district heating. On January 1st of 2014, HOFOR overtook the Amager Power Plant from Vattenfall, a purchase that was driven by the City of Copenhagen's desire to be carbon neutral by 2025. At the time, the power plant had one unit based on coal, and another on wood pellets. In the spring of 2020, the coal unit was closed, and a new wood chip-fired unit was brought online.

This means that at its Amager site - located right next to the ARC waste-to-energy facility mentioned above-HOFOR now operates two biomass-fired CHP units. Amager power plant's Unit 1 (referred to as AMV1) can produce 250 MJ/s heat and 68 MW electricity, with an annual wood pellet consumption of roughly 250,000 tonnes. The new wood chip-fired unit (AMV4) has a heat production capacity of 400 MJ/s heat and an electrical capacity of 150 MW. This is anticipated to use roughly 1.2 million tonnes (moist weight) of wood chips per year. The Amager site is located by the sea, and all biomass fuel inputs are currently received by ship. The majority of wood chips come from the Baltics, Germany, Brazil, Norway, and Spain. Sustainability, price and security of supply are the most important factors in determining the source of fuel inputs.

HOFOR is currently investigating various options when it comes to implementation of CCS, including capture for AMV4. If carbon capture was implemented on the new wood chip-fired unit, 1.2 million tonnes of wood chips corresponds to roughly 1.2 million tonnes of CO_2, which with an assumed 90% capture rate would result in nearly 1.1 million tonnes of captured CO_2 per year.

In terms of technological options for the capture, HOFOR is still in a fact gathering phase, and has no concrete plans to implement carbon capture at this point, so it is too early to say what technologies HOFOR would potentially select. However, HOFOR would place emphasis on technologies that have a high technology readiness level (TRL). This information gathering phase includes investigating both options for storage and potential utilisation in the production of other fuels. However, from a technical perspective, HOFOR does not deem the challenges associated with establishing a capture facility to be overwhelming. Carbon capture requires a great deal of heat (usually steam), which can be made available from one of the steam cycle power units on site. This is not "low-cost" heat, but much of this heat can be recovered and boosted via heat pumps for use in district heating. As the Amager power plant is a large supplier of district heat, process heat recovery would be an ideal aspect to investigate in connection with carbon capture at the Amager power plant. One thing that could prove more challenging however is integration of new heat pumps into the existing plant.

2.2 POST-CAPTURE OPTIONS: STORAGE, UTILIZATION OR CLUSTER?

HOFOR is still early in its analysis of potential options so if carbon capture was implemented, it is unknown whether the CO_2 would be utilised onsite or exported for storage or use elsewhere. However, due to potential spatial restrictions, it may be difficult to utilise large amounts of CO_2 on site. HOFOR is open to partnerships and clustering in a possible further investigation into BECCSU as the complete setup for such a system requires massive investment, large amounts of space and involves uncertainties and risks. Such cooperation should be based on potential synergies with other energy producers within waste-to-energy, power producers, offshore wind parks, end users of liquid electrofuels, etc.

3 Moving to deployment – business models and policy options

HOFOR is bound by a number of regulatory framework conditions, and one of the most important is that it may not undertake investments that make heat more expensive for its customers (Heat Supply Law). HOFOR's interest in exploring BECCUS options is thus to get a better understanding of what it would cost to capture and potentially utilise CO_2 in a situation where another party expresses interest in paying HOFOR to do so.

HOFOR does not see direct policy support as the only solution for capture implementation at the Amager power plant. However, given the current framework conditions, HOFOR would have to be compensated in some form in order to not raise the price of heat for its consumers. For example, if some form of policy, regulation, or industry desire increased airlines willingness to pay for green jet fuels, then HOFOR could be in the position of supplying CO_2 to PtX production. Or, as a more direct form of policy support, HOFOR could imagine a system involving a feed-in-tariff for delivered CO_2. In terms of whether support comes from a local, national, or European level is likely not too significant, the most important aspect in any form of support is long-term certainty, which Denmark has a very long tradition for. Given the Danish government's 70% reduction target in 2030, a federal driver could be likely in a Danish context.

As for other issues pertaining to taking the project from concept to commercial deployment, potential challenges could be the additional noise that the unit may produce, as the plant is located relatively close to a residential area, as well as ensuring that there is enough space to establish new infrastructure.

References

Becidan, M. (2021) Deployment of bio-CCS: case study on Waste-to-Energy, IEA Bioenergy

Bergström, S. (2020). Koldioxidavskiljning på ett biobränsleeldat kraftvärmeverk : Simulering av två avskiljningstekniker vid Karlstad Energis kraftvärmeverk, Heden 3. http://urn.kb.se/resolve?urn=urn:nbn:se:kau:diva-78918

Stockholm Exergi (2020). Bio-CCS - Stockholm Exergi. https://www.stockholmexergi.se/om-stockholm-exergi/about-stockholm-exergi/negative-emissions/bio-ccs/

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