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Is There a Future for Carbon Capture and Storage?

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Abstract: The article discusses the political economy of CCS. The IPCC reports gives CCS a significant role in keeping global warming somewhere between 1.5 and 2 degrees Celsius, but still there is very few installations in operations and very few in the pipeline. This raises the question of why the diffusion of CCS has been slow and seem to slow down rather than speed up. First the paper discusses the question: When there is consensus the take-off of CCS depends on a high CO2 price, why is the price so low? Secondly discusses: What would happen if the CO2 price was 100 USD or higher? Would CCS then be the preferred way to reduce emissions or would other technologies be not only cheaper, but also faster and easier to implement? The paper concludes that the question the role of CCS in mitigating climate change also must be formulated as *political* problem, where the political/electoral effects of a high CO2 price plays a key role and needs to be taken much more *explicitly* into consideration than has been done so far. The paper uses primarily the fate of CCS in Norway as a case study of the political economy of CCS.

Keywords: CCS; Carbon Capture and Storage; carbon pricing; emission trading income distribution; just transition

JEL Classification: Q54; Q58; Q52

1. Introduction

The purpose of this article is to discuss the political economy of CCS. CCS is of course not the only technology that is needed in order to reach a near total reduction in CO2 emissions by 2015, but it has been and is given a significant role, not only in the IPPC reports, but also in the national climate policy in many countries. in IPCC reports gives CCS a significant role in keeping global warming somewhere between 1.5 and 2 degrees Celsius, but still there is very few installations in operations and few in the pipeline. This raises the question of why the diffusion of CCS has been so slow, and seems to slow down rather than speed up. The obvious answer is that that investing in CCS is not profitable. There is a general consensus that to make it profitable the price of carbon needs to be at significantly higher level than today. That raises the question: When there is consensus the take-off of CCS depends on a high CO2 price, why is the price so low? Secondly the paper discusses: What would happen if the CO2 price was at a level sufficient to make CCS profitable, let's say 100 USD or higher? Would CCS then be the preferred way to reduce emissions or would other technologies be not only cheaper, but also faster and easier to implement? The paper

concludes that the question the role of CCS in mitigating climate change also must be formulated as *political* problem, where the political/electoral effects of a high CO2 price plays a key role and needs to be taken much more *explicitly* into consideration than has been done so far. The paper is based primarily on the experiences and the fate of CCS so far in Norway as an empirical background of the political economy of CCS, (Jakobsen et al., 2017; Karimi & Komendantova, 2017; Rottereng, 2018; Anker, 2018; Tjernshaugen, 2008, 2011), but we will not discuss the Norwegian case in particular, since the Norwegian experiences just shows the importance of the key factors influencing the diffusion of CCS, which are the cost of CCS and the price of carbon.

2. Methodology and Structure of the Paper

This paper aims to answer the question: Why CCS is not taking off, despite being in operation for many decades? CCS is basically a mature technology, while there is of course still room for improvement existing methods. There are also introduced new methods, like the Allam-Fetvedt oxy-fuel method, for an overview of the state of the art of various CCS technologies, see (Sifat & Haseli, 2019). The methodology of this paper is a brief descriptive analysis, pointing to some well-known stylized facts as a starting point for an analytical discussion of the future of CCS. Since this article is primarily a discussion of the political economy of CCS and objective and due to space limitations, we will start out by very briefly describing the most important stylized facts without a lot of references to the literature. In our opinion a lot of references is not necessary. The stylized facts of CCS that are important for our discussion are not controversial. They are summarized in a handful of reports. The key report is of course the yearly report from The Global CCS Institute. The "Global Status of CCS 2020" is a very informative and readable publication with many nice and graphs, (Institute, 2020). To our knowledge nobody claims that the information provided by the institute it is not facts based, on the contrary, it is the common starting point for all analysis of CCS as a mitigation policy. The same goes for The World Bank Group report on "State and Trends of Carbon Pricing 2020", (World Bank, 2020). Actually, the data in these two reports do not change very much from year to year. This slow progress of both CCS and carbon pricing is closely related for reasons that we think is essential to understand in order to understand "what must be done" to borrow a famous phrase from Lenin. Then there are the IPCC reports, with an increasing "alarmistic" message. In this paper will use the IPCC report on 1.5 degrees, where both CCS and carbon pricing is mentioned many times, 375 and 57 respectively. One can of course discuss of the report gets all the uncertainties right, if the reports are too afraid of being even more alarmistic, but for our present purpose that is absolutely not an issue. What is the issue is that although carbon price and CCS is mentioned all the way through the report, there is in our opinion not any real discussion of the relation between carbon price and diffusion of CCS, even less about what can be done to increase the price of carbon. From a more methodological point of view, we think it us fruitful to look at getting to the target of zero emissions in 2050 as an optimal control problem, where the price of carbon is they key control variable which can be used to get the quantum of CO2-emissions to the desired level, that is to zero as soon as possible, in 2050 the latest.

Finally, there are many articles and books on CCS. Regarding sources for information about CCS policy formulations, our impression is that it is reports like the three reports mentioned above mentioned, that policy makers and climate policy NGOs reads. These mostly from consultancy firms or various types of contract research, which is by policy makers, trade unions and NGOs. These are generally of good quality, mostly based on either academic or own research. When we in this paper will give relatively few references to this vast literature, it is because the key points we want to discuss is described and mentioned in the report on the status of CCS, status of carbon pricing and in the IPCC report on the need for CCS.

The paper is structured as follows. In section 3 we show that CCS is spreading slowly. In section 4 we discuss why carbon, as a way to price CO2 emissions, is not higher, pointing to the effects on the income distribution and the political effects of the changes in the income distribution.

3. The Problem – CCS Spreading at Snail's Pace

The figure below shows the development of CCS capture capacity in various stages of the facilities development.

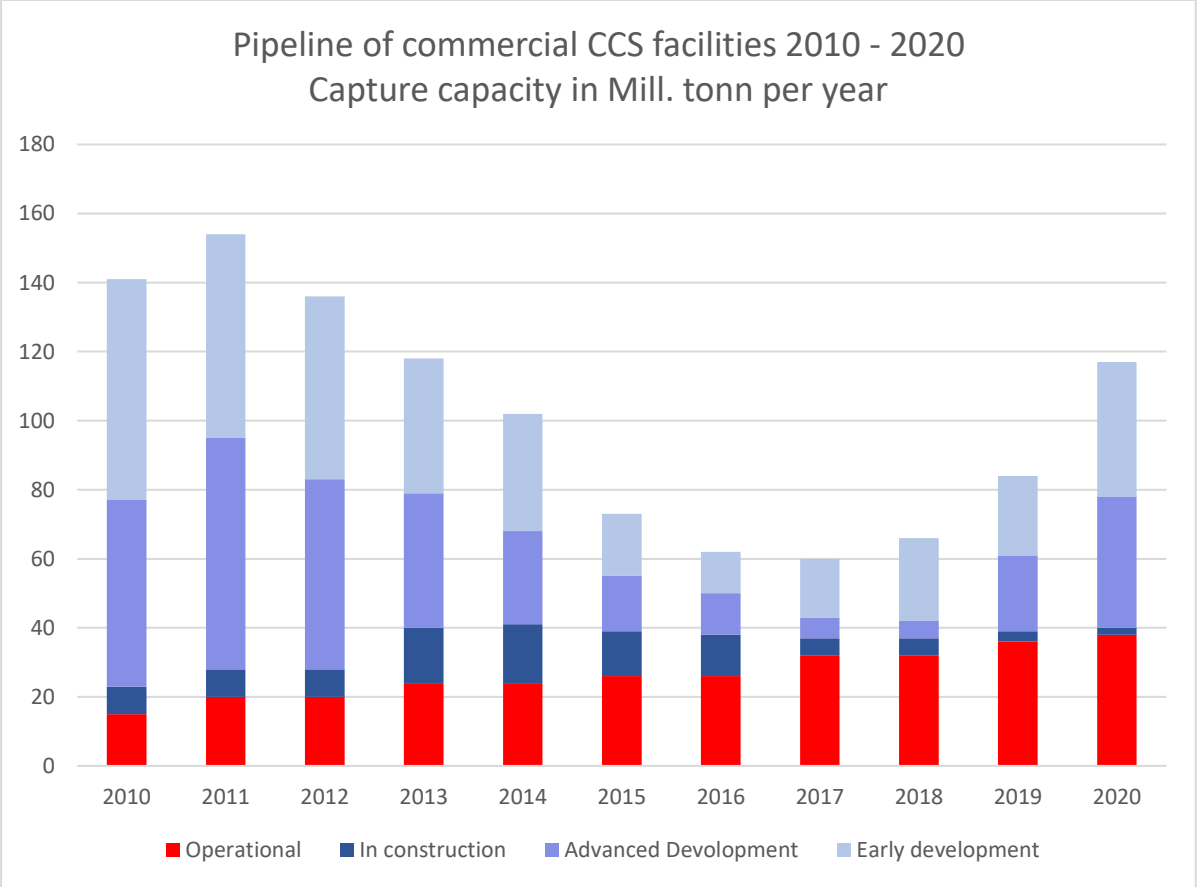

Figure 1. Overview of CCS installations (Institute, 2020, p.17)

The figure shows that the actual capture and storage capacity in 2020 is higher (red color) than 10 years ago but growing very slowly. When it comes to future capacity it does not look very good either, (Oei & Mendelevitch, 2016). This would of course not be a problem if

today's capacity was anywhere near what is stated in the Global CCS report as needed. The quantum must increase "from around 40 Mt of CO2 per annum today to around 5.6 gigatons (Gt) in 2050 – a more than hundredfold increase" according to the report. Just to make it clear, the number of 5.6 gigatons can of course be discussed, but for our present purpose it is not important at all if that number is 4 Gt og 7 Gt. The point we want to make is that CCS capacity is not in the near future anywhere near the need, that is anywhere near fulfilling the role assigned to it in the last IPCC report. This in our opinion makes it imperative to discuss what can be done to speed up the diffusion – or alternatively, realize that CCS is not going to make it, and that one must immediately start looking for other solutions.

The reason why it is spreading so slowly is of course no mystery, it is the low price of carbon. From the World Bank Group's yearly reports on carbon pricing it is clear that the primary reason is that in most countries carbon is not priced at all, only about 16 percent of the world's emissions are taxed (World Bank, 2020). Even in those countries, regions where it is taxed, the carbon price is low. Since the EU ETS (emission trading system) is the most important carbon pricing area, we will use the current price in the EU ETS as a reference price, for simplicity 30 Euro. The average the last ten years has been much lower, but for our discussion, making it 20 or 40 Euro does not matter substantially. What is clear – and mentioned by everybody is that a 30 Euro carbon price is way too low to make CCS worth investing in. Consequently, it is only when CO2 is used for enhanced oil recovery (EOR) or supported by very generous government subsidies, that it is profitable for the individual firm.

The low carbon price is not a problem for CCS only, as IPCC puts it:
"The available literature indicates that mitigation pathways in line with 1.5°C pathways would require stringent and integrated policy interventions (very high confidence). Higher policy ambition often takes the form of stringent economy-wide emission targets (and resulting peak-and-decline of emissions), larger coverage of NDCs to more gases and sectors (e.g., land-use, international aviation), much lower energy and carbon intensity rates than historically seen, **carbon prices much higher than the ones observed in real markets**, increased climate finance, global coordinated policy action, and implementation of additional initiatives" ((IPCC, 2018), p. 148, our emphasis).
While the concept "income distribution" is occurs only once in the IPCC report, the report is clearly aware of the distributional effect of a carbon tax on income distribution: "First, in the absence of countervailing policies, *higher energy costs have an adverse effect on the distribution of welfare*. (p. 375, our emphasis).

3.1. CCS, the Carbon Price and the Yellow Vests

The 1.5 degree IPCC report came out in 2018, before "yellow vests" came onto the streets in Paris. In a nutshell the yellow vest movement showed clearly why the carbon price is so low worldwide. If governments try to tax carbon without taking the "adverse effect of the distribution of welfare" into consideration, that price increase will be met with more or less massive and/or militant protests. In our opinion, and our first conclusion is that those who faith in CCS must deal with this income distribution problem, that the only way to get the

carbon price that CCS needs is to increase the carbon price in a socially just way. That is in a way making the yellow vests benefit from a higher carbon price. There are many ways to do that, but one of the simplest is the "Carbon Fee and Dividend" (CFD) system proposed by climate researcher, James Hansen. The principle is very simple, (Foster, 2013). You put a tax on fossil fuel at the "source", that is collecting it from producers and/or importers of fossil fuel. They will then include the increased cost in the prices they charge their customers, and that way price increases will spread in the economy until the final customers, mostly households will "pay the bill". If the government at the same time redistributes the collected carbon tax revenue with an equal share to all legal citizens, the CFD will be a "Robin Hood" redistribution system. The system will be taking tax revenue from the rich with a large (above average) carbon footprint and giving to the "poor" that statistically have a lower than average carbon footprint, since there is a close correlation between the size of the normal consumption basket and carbon content, so the total price of a person's consumption is a very good indicator of the carbon footprint. There is a lot more to be said about carbon tax and distribution, how to deal with exports and imports of goods, but that is not important in this context. A very good general introduction to carbon pricing is the so-called Stiglitz-Stern report,(*Report of the High-Level Commission on Carbon Prices*, 2017). A Robin Hood carbon tax might sound like left wing Keynesian policies, but that is not necessarily the case. In the US a group of former high level republicans have endorsed the idea, (Council, 2017). We will not discuss in this article the very interesting question why both left-wingers and Reagan-republicans can support the same policy. The point we want to make is that anyone who is serious about CCS has to be even more serious about how to find a solution to the problem of how to make it possible in a democracy to rise the carbon price and win elections. A CFD policy might be one way to do it. When the Global CCS Institute report just in one sentence express the obvious fact that the carbon price is way too low, writing that: "Stronger policy to incentivize rapid CCS investment is overdue", this is a very clear understatement, when the distributional effects of a higher carbon price is the main reason why it is still way too low to "incentivize" rapid investment in CCS.

There is actually more written on the key question of income distribution, that is social justice in the latest IPCC report. A lot of good points and good references are given in chapter 4.4.5.2 "Carbon pricing: necessity and constraints", but it speaks volumes that the question of the carbon price is not even mentioned, not to speak of brought to the forefront as "what must be done" in the "Summary for policy makers" The word "price" does not appear even once in this "Summary for policy makers". There is a short paragraph in the "Technical summary" (p. 33).

3.2. The Question of the Level of the Carbon Price

There are very many estimates of the carbon price needed in order to keep augmentation of the global temperature below 1.5 degrees or 2.0 degrees, and for CCS to take off. This is reflected in the estimates in the IPCC report. From the chapter "2.5.2.1 Price of carbon emissions", starting on page 152, we have extracted the following table:

Table 1. IPCC overview over estimates for the price of a ton of CO2, in 2010 USD

	2030	**2050**	**2070**
1.5 degrees	135–6,050	245–14,300	420–19,300
2.0 degrees	15–220	45–1,050	175–2,340

The report has just a brief remark regarding the estimates: "The wide range of values depends on numerous aspects, including methodologies, projected energy service demands, mitigation targets, fuel prices and technology availability…" (p 152). One might argue that given such a great variation it would have been better to round the numbers more to indicate the uncertainty and variation of the estimates. Use 150–6,000 for the first interval, 250–14,000, but this not important, because the James Hansen CFD proposal has as it's "driving force" an *ever-rising* carbon price. One has to start with a certain price and have rule for how much the carbon price should increase each year. If one started in the EU ETS for example with 40 Euro, up roughly 10 Euro from the highest level the last year (2020) and increased it by 10 Euros every year, this would then reach 80 Euro in four years. Since the tax is collected at the "source" the whole economy will be affected. Today the EU ETS only covers 40% of the economy and does not include transport. The political motivation for excluding transport was and is fairly obviously, because if transport was included, then the gasoline price would rise as the EU ETS carbon price kept rising. An economy wide (socially just) carbon tax would of course have a bigger effect, not only due to coverage, but also due to predictability. All actors in the economy can calculate in a rational, "deterministic" way. After 3–4 years the effects of the ever-rising carbon prices would be clearly felt. The effects could be using various indicators, not the least the sale of fossil. One could observe the effects in different markets and for different social group. Based on such data, the democratic process could consider in/decreasing rise of the carbon price. The carbon price would then become a "force" one could use to get a dynamic system like an economy in the direction one wants and at hopefully at the desired speed.

4. Carbon Price and Substitution

In this section we will in typical economist way "assume" that the carbon price by some policy (miracle) has reached a level where CCS could be profitable. If that is 100 Euro or 200 does not matter. If it is an ever-rising carbon prices, it will reach the "take-off" level sooner or later – and all market actors will know that. Since CCS is profitable when used to extract more oil, we think that the 100–200 Euro range is not order of magnitude wrong. What we want to discuss briefly is the substitution effect of such a high price, because this question which is discussed very little, practically not at all in the literature as far as we can see. In Norway there has been a public debate in relation to the CCS project capturing CO2 from cement production (Norcem) and from burning the household waste produced in the wider Oslo area (Fortum Oslo). Both projects are related to the Northern Light project, (Institute, 2020, p. 22).

When it comes to cement, the emissions are both from using fossil fuel to get the required heat and from the chemical reaction that creates cement. It is the latter that really needs CCS.

Fossil fuel can be substituted for producing heat. The recent discussion is if actually will use cement as much as we do today when the price of cement is significantly much higher caused by either only a tax on fossil fuel and/or a tax on CO2-emissions. In Norway glue wood has been used for decades, for example in the construction of the Oslo airport. Recently an 84-meter-high glue wood building was built (Mjøstårnet), so clearly glue wood could easily become cheaper when cement becomes significantly more expensive. In China it would probably be glue bamboo that could be used. The great advantage of using wood and especially bamboo is that wood and bamboo stores carbon and using it to a much larger extent would be an example of "negative emissions". Concrete is used for a lot of construction purposes, like bridges where wood and bamboo might not have the strength etc. needed (Hassan & Johansson, 2018), but production of steel for example does not necessarily create emissions,. There are substitutes for the fossil input to the steel production process, (Greenbiz, 2020).

When it comes to household waste the question is if it would not be better to "get rid of the problem" that is to reduce the amount of waste that needs to be burned by increased recirculation, refilling etc. If there was a way to make the consumer to be able to choose between a product with a "need-to-be-burned" packaging with a higher price than the "substitute" recyclable product that could be more rational to invest in getting into place than billions of Euro for an end of pipeline solution. A solution which might be replaced by recirculation because we need to reduce the extraction of finite resources or protecting the oceans from plastic waste.

In a way there has been a major substitution already because there are very few coal and gas power plants with CCS in operation. The reason is that electricity based on wind and solar has become much cheaper over the last decade. Of the CCS projects in early or advance development there are more intended to be used in power production, but if the price of electricity produced by solar and wind continues to fall, even when the cost of storage is included, they can "crowd out" power plants with CCS. This is a story we already know from Norway. The original argument for building CCS at Mongstad (on the West coast of Norway) was to "clean" a natural gas power plant. This power plant (Kårstø) never became economically viable, because it could not compete with Norwegian hydro-power and there was an increasing amount of wind-power being build. The company could not see any possibility for profitable operation then next 10 to 15 years. In 2017 the gas power station was taken apart, the valuable parts like the turbine was sold.

5. Conclusions

There is a gap between the emissions reductions needed to keep global temperature between 1.5 to 2.0 degrees. CCS has been assigned an important role in reducing emissions for decades. The capacity to do so have grown very slowly the last 10 years and needs to be increased at least hundredfold. The reason for this slow growth is the low price of carbon, which gives no incentive to invest in CCS. A global carbon price does not exist, and even in EU where it is well established, it has only recently reached 30 Euros, which is still only half of the price needed by the most optimistic estimates of the carbon price needed for CCS to be

profitable. In our opinion the reason why the carbon price is so low is that any attempt to increase the carbon price without simultaneous and very "visible" compensation for below-median incomes are politically impossible. The yellow vest movement in France against Macrons modest increase in the price of petrol indicates that very clearly. Even if there was implemented policies that were able to get the carbon price to at least 100 Euros in a socially just way, it might not lead to the take off-of CCS. The main reason is that wind and solar power, even with the extra costs incurred by the need to build storage would be significantly cheaper. When it comes to emissions not resulting from burning of fossil fuels, like the production of cement, burning of household waste etc. a high carbon price might lead to substitution. Glue wood and bamboo, fossil free steel, composite materials could become cheaper substitutes for concrete as building materials. If a price is put on products that result in emissions from household waste being burned recycling might increase to a degree that eliminated any massive emissions from household waste. If this prognosis is correct, CCS might never take off and should not any longer be a part of "the solution" to the climate crisis.

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