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Climate and Air Policy Goals Less Costly | *Demand for Biomass Decreases*

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Biomass-Energy with Carbon Capture and Storage Should Be Used Immediately

Johannes Bollen
Rob Aalbers

Summary

The European Union aims at reducing its greenhouse gas emissions in 2050 by 80-95% in order to prevent climate change. In this Policy Brief, we analyse the potential role of negative-emissions technology in reducing these emissions. A prime example of such a technology is the gasification of biomass in specially designed power plants that capture CO_2 and store it underground (Biomass Energy with Carbon Capture and Storage, or BECCS). We conclude that this type of technology substantially reduces climate policy costs.

Total cost savings from redirecting biomass to BECCS in an 80% reduction scenario equals to approximately 0.3 trillion (300 billion) euros, while in a 95% reduction total cost savings increase to as much as 7.7 trillion (7700 billion) euros. Depending on the EU's climate ambitions, total savings per capita are between 500 and 15000 euros.

Surprisingly, redirecting biomass to BECCS decreases the global demand for biomass. The reason is that the use of BECCS increases the EU's carbon budget. This enables EU-countries to use more fossil energy without having to jeopardise the overall emission reduction targets. This, in turn, lowers the price of energy in the EU, which results in lower demand for biomass and associated land-use requirements. Thus, it also alleviates pressures on food production and forests.

The increased use of fossil fuels means that the reduction in the EU's air pollution is less substantial. However, by taking additional and relatively cheap measures, such as selective catalytic reduction, the EU member states can easily undo these unfavourable impacts on their air quality. Notice that, concerns regarding the safety of CO_2 storage can be alleviated by simply prohibiting onshore storage of CO_2.

Redirecting biomass to BECCS is also attractive from an economic perspective. This also holds when accounting for the extra mitigation costs to maintain air quality. Because of the extra carbon budget, more CO_2 can be emitted in the non-electricity sectors without having to jeopardise the overall emission reduction targets for 2050. And although electric driving and zero-energy homes have positive effects in terms of both climate and air quality, we find that their large-scale application before 2050 is much more expensive from a societal point of view.

However, in order to actually reduce climate-policy costs, the EU needs to rectify a flaw in its Emissions Trading System (ETS), as in the current system, firms are not rewarded for their investments in negative-emissions technology. A correction of this flaw is needed to re-establish the level-playing field between all emission-reducing technologies.

But, even if this flaw were to be corrected, firms would still face insufficient incentives to invest in BECCS. The issue is that BECCS changes the efficient distribution of the EU’s carbon budget between the ETS and the non-ETS sector. More specifically, the non-ETS carbon budget needs to be increased at the expense of the ETS carbon budget in order to establish

uniform CO_2 pricing across the economy. Only then will the EU be able to reduce climate-related costs by 0.3 to 7.7 trillion (300 to 7700 billion) euros.

1 Introduction

At the UN climate change conference in Paris in 2015, world leaders reconfirmed that the increase of global mean temperature should be limited to 2°C. In order to achieve this ambition, global greenhouse gas emissions need to decline by 2050 by 40-70%, compared to 2010 levels.[1] Well-known emission reduction measures include the use of wind turbines and solar cells (photovoltaic systems) in power generation, energy savings technologies and electrification of transport. Biomass is also expected to play an important role in reducing greenhouse gas emissions.

Biomass is already an important source of energy. On the global level, with a share of 10%, it is the fourth most important source after oil, coal and natural gas. This share represents a total of 50 ExaJoules (EJ),[2] and includes enormous diversity in use. In developing countries, biomass is mainly used for domestic heating, lighting and cooking. In 2008, this traditional use of biomass, mainly in the form of wood, straw and manure, comprised around 80% of its' total global use. The remaining 20% is made up of more industrial and modern uses of biomass. Modern uses typically involve conversion to make the combustion process more efficient. Examples include cars running on biodiesel from rapeseed and heating using biogas from manure and waste.

Global demand for biomass is expected to increase due to climate policy, because in many cases it is the only available zero-carbon option. Aeroplanes can fly on biofuel, but because of battery weight, not on electricity. Battery weight also limits the use of electricity as a fuel in heavy transport. Furthermore, biomass is the primary zero-carbon substitute for oil in the chemical industry. In total, projections of annual biomass demand for 2050 vary from 70 to 190 EJ, and may even be as high as 300 EJ.[1]

The European Union (EU) also expects climate policy to induce a greater use of biomass. For example, in its Impact Assessment in support of its Energy Roadmap 2050, the European Commission (EC) projects the total use of biomass in Europe to increase from 5 EJ in 2010 to around 11 EJ by 2050.[3] Notably, the EC also predicts a threefold increase in the use of biofuel, over the same timeframe.

The large increase in biomass demand in Europe and other parts of the world raises questions about how much biomass the planet could produce without jeopardising food production. An additional risk is that biomass production may induce further deforestation. Although, estimates of the sustainable biomass potential are uncertain, for 2050 a

[1] IPCC (2011).
[2] See IPCC (2011). 1 exajoule = 1000 petajoule = 10^{18} joule. In comparison, primary energy use in the Netherlands in 2014 was 3.2 EJ. In the EU 28 this was over 67 EJ (Source: Eurostat).
[3] EC (2011).

sustainable production of 150 EJ seems to be feasible.[4] At this production level the consequences for both food supply and forests will be limited.

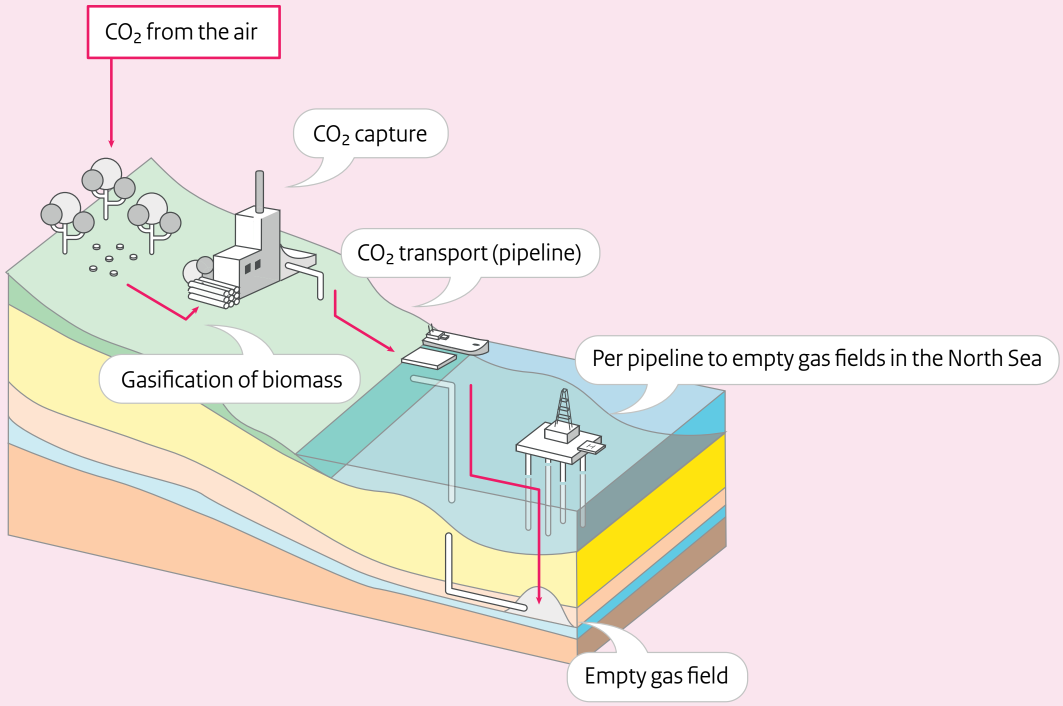
Negative emission technology

CO_2 capture and storage (CCS) can be applied in all installations that generate electricity using coal, natural gas or biomass. Using this technology, a net CO_2 emission level of close to zero can be achieved, as emissions no longer enter the atmosphere.

Moreover, if power plants use biomass instead of coal or natural gas, the net CO_2 emissions over the entire chain will even be negative – as the entire chain, from biomass production to its conversion and subsequent storage of CO_2, extracts carbon from the atmosphere. Biomass (trees and plants) takes up CO_2 during the growth process and storage prevents this CO_2 from re-entering the atmosphere during the combustion or gasification of biomass.

In this policy brief we will use the acronym BECCS to denote a power plant that produces electricity through the gasification of biomass and subsequently captures and stores the CO_2.

A biomass power plant with carbon capture and storage



[4] IPCC (2011) and PBL (2012).

Because of the limited availability of sustainable biomass, consensus has emerged over recent years on the principle of 'cascading'. The idea behind this principle is that low-value applications of biomass will only be considered after all possibilities for high-value applications have been exhausted. Unfortunately, there seems to be no clear definition of what would constitute either low- or high-value application of biomass.

For example, in a letter to the Dutch House of Representatives, the Dutch Cabinet argues that it is impossible to draft a framework for assessing the preferred use of biomass.[5] Nonetheless, the Social and Economic Council of the Netherlands (SER) advises that biomass be reserved for activities for which there are no technical alternatives, such as in aviation and shipping.[6] The Royal Netherlands Academy of Arts and Sciences (KNAW), in its vision document, calls for zero biomass use in energy supply, unless it originates from waste.

This policy brief investigates what would constitute high-value applications of biomass from a welfare perspective, the possible bottlenecks of current regulation hampering these high-value applications, as well as how large the advantage would be of removing those bottlenecks.

Specifically, if Europe were to apply biomass in power plants, would the advantages of doing so outweigh the disadvantages? And what should be the preferred type of power plant? Should that be the current system of co-firing biomass in coal-fired power plants, or would it be better to design and build biomass-only power plants? And, finally, should all those power plants use CCS technology, thus creating the possibility of negative emissions (see Box "Negative emission technology")?

The answers that we provide to these questions in this policy brief contribute to the discussion on biomass cascading. In addition to the direct economic effects, our analysis also considers possible negative impacts on the availability of resources for the chemical industry, the use of fossil fuels, deforestation and food production.

2 Invest in biomass-fired power plants with carbon storage

What constitutes high-value applications of biomass, if the EU is aiming for an 80% reduction in its greenhouse gas emissions by 2050, compared to 1990 levels? In order to obtain more insight into this issue, we conduct the following thought experiment (Figure 1).

First, suppose that all European grown biomass goes to the chemical and transport sectors. Thus, there is no BECCS. Subsequently, reduce the application of biomass in the chemical and transport sectors and use this amount of biomass to produce electricity with BECCS. Overall,

[5] The Dutch House of Representatives (2014).
[6] SER (2010). See also: RLI (2015) and Greenpeace International, GWEC & EREC (2013).

we use no more biomass, we only change the way it is used. For simplicity, we also assume no import of biomass into the EU, but allow inter-EU trade of biomass.

For our thought experiment, we keep the existing emission reduction targets. Because CO_2 storage from biomass leads to a reduction in emissions, this creates possibilities for an increase in emissions elsewhere in the economy. In our thought experiment, the reduced amount will be fully utilised elsewhere.[7]

Subsequently, we determine whether or not the EU's total mitigation costs decrease due to the application of BECCS.[8] As long as total costs decrease, we continue to increase the amount of biomass used in BECCS. We end our thought experiment when mitigation costs no longer decrease.

Finally, we compare the EU's mitigation costs over the 2015–2050 period in a situation with and without the use of BECCS.[9] We have conducted this thought experiment not only for the 80% emission reduction target for 2050, but also for reductions of 85%, 90% and 95%.

Figure 1 **The thought experiment and the total costs of emission reduction, over the 2015–2050 period (in trillion euros)**

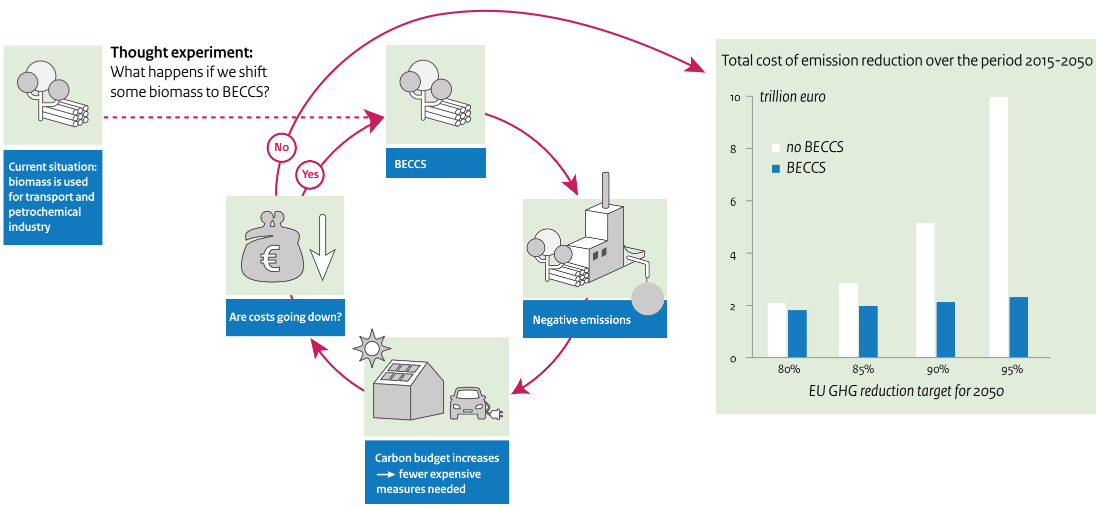


Figure 1 shows that the total emission reduction costs for an 80% target will be equal to 2.1 trillion (2100 billion) euros in a situation without BECCS.[10] Applying BECCS would reduce those costs to 1.8 trillion (1800 billion) euros. The resulting cost saving of 0.3 trillion (300 billion) euros can be attributed BECCS' negative emissions, as relatively expensive emission reduction measures in other sectors are needed less.

[7] All calculations were conducted using the MERGE-CPB general equilibrium model. See Bollen (2016) for an extensive description of the model and the analyses conducted.
[8] Total emission reduction costs include all relevant costs incurred in Europe. This, for example, includes the (additional) costs of renewable energy technology, the costs of energy saving and (additional) fuel costs.
[9] Unless stated otherwise, all costs over the years from 2015 to 2050 are expressed in 2015 prices using the appropriate discount rate.
[10] This is 0.24% of the net present value of GDP from 2015 to 2050.

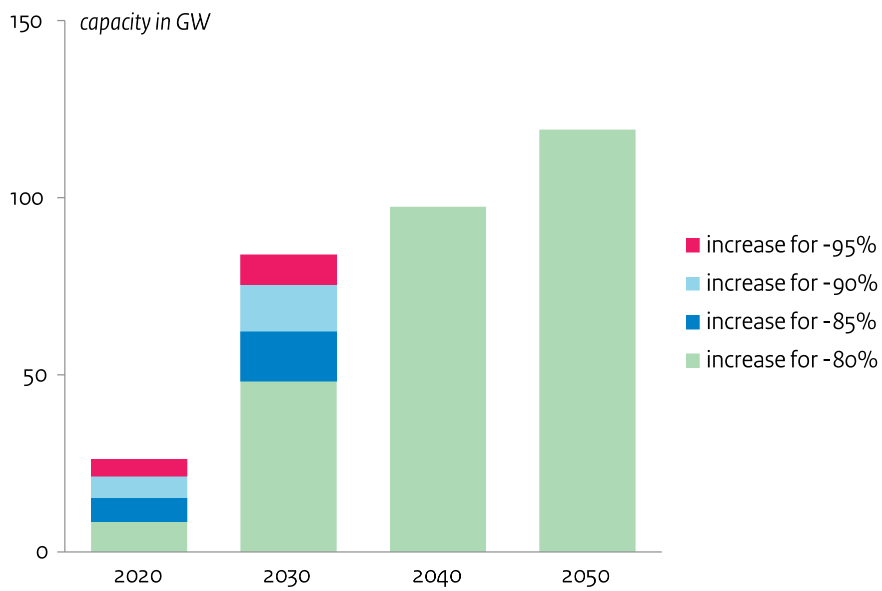
For BECCS, the costs of reducing 1 tonne of CO_2 are about 115 euros. The use of BECCS means that there is no need for more expensive CO_2 reduction measures elsewhere in the economy. Those measures typically cost between 115 and 340 euros per tonne of CO_2. The total cost advantage thus created equals the 0.3 trillion (300 billion) euros mentioned above.

If the EU wishes to be more ambitious and wants to reduce emissions by 85% or more, this means more and usually more expensive measures must be taken to meet those more stringent targets. Without BECCS, increasing the reduction target from 80% to 95% will increase the emission reduction costs from 2.1 to 10.0 trillion (from 2100 to 10,000 billion) euros (Figure 1) - a cost increase of as much as 7.9 trillion (7900 billion) euros.[11]

However, with BECCS costs will only increase from 1.8 to 2.3 trillion (from 1800 to 2300 billion) euros – a cost increase of 'only' 0.5 trillion (500 billion) euros.

The advantage of BECCS is therefore much greater for more ambitious targets, because those targets require a larger number of measures and more expensive measures. Those more expensive measures make the use of BECCS even more attractive. After all, the use of these types of power plants will remove the need for the most expensive measures, such as electric driving and energy-neutral housing, which will be necessary to meet the targets of 85% or more.[12]

Figure 2 Optimal investments in BECCS, under various reduction targets for 2050



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[11] This is 1.3% of the net present value of GDP from 2015 to 2050.
[12] An increase in the use of biomass does not explain the larger cost advantage under more ambitious reduction targets, because in all variants – reduction targets from 80% to 95% – the use of biomass remains at 9.6 EJ.

In order to realise the advantages of BECCS, it is important that investments in these power plants start as soon as possible (Figure 2). A 2050 emission reduction target of 80% requires a European-wide production capacity of close to 10 GW[13] by 2020 and nearly 50 GW by 2030. And for a target of 95%, this would be 25 and 85 GW, respectively. By 2050, the optimal capacity is approximately 120 GW, implying that BECCS supplies around 12% of all electricity within Europe.

Immediate investments in BECCS are needed, because the accompanying infrastructure requires time to build. This, for example, concerns the local supply of biomass, the time required to obtain permits, plant construction time, development of local expertise, and the infrastructure for the CO_2 storage itself. If the first substantial investments in BECCS do not take place before 2020, its capacity levels in 2050 will be insufficient to realise the above-mentioned cost savings.[14]

We would like to stress that these figures are not based on random assumptions about the costs of expensive measures, such as electric vehicles and energy-neutral housing. The application of BECCS becomes interesting as soon as the 2050 carbon price exceeds 115 euros per tonne.

For 2050, this is not an unreasonably high price. For example, the EC's Impact Assessment assumes the CO_2 price without BECCS will be between 265 and 350 euros per tonne, by 2050.[15] At those price levels it would be very profitable to invest in BECCS.

The Impact Assessment, moreover, also assumes a reduction target for 2050 of only 80%. More ambitious targets would result in higher carbon prices and, thus, in even greater BECCS-related cost savings.

3 Reform the EU Emissions Trading System

Although the economic benefits of BECCS are large, the incentives to invest in BECCS will be negligible because current regulations on CO_2 storage are distorting the market. In addition, the carbon price is still too low because the ETS contains too many emission allowances. BECCS, in particular, is disadvantaged by this situation (see Box "No business case or lacking government policy?").

Within the EU, the ETS directive determines the boundaries for carbon capture and storage (CCS).[16] The use of fossil fuels releases CO_2. However, if a company captures and stores this CO_2, this company does not have to hand in any emission allowances. Therefore, this provides them the incentive to do precisely that (see Figure 3).

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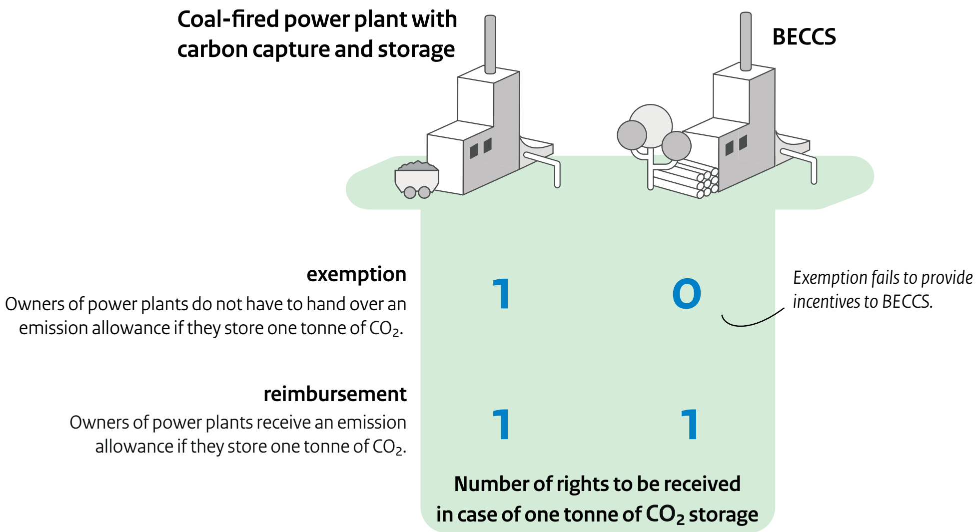
[13] Assuming a 50% load factor, a 1 GW power plant is able to produce electricity for about 1 million households.
[14] The same argument also applies to investments in other new technologies, such as wind and solar energy.
[15] See Table 37 in EC (2011). The CO_2 prices in that table have been converted into 2015 prices by using the HCIP inflation index.
[16] See European Parliament and Council (2003). In addition to the ETS directive, the CCS directive sets the technical framework for CO_2 storage (European Parliament and Council, 2009).

Figure 3 Number of emission allowances earned by a power plant



Unfortunately, this emission-trade exemption does not provide incentives for BECCS to capture and store CO_2, as the use of biomass, in contrast to that of fossil fuel, is already exempt from the emission trade. An additional exemption on top of the first exemption will not provide any further incentive (see Figure 3).

No business case or lacking government policy?

If BECCS is so profitable, then why are investors – who are so eager to invest in wind turbines, solar cells and electric vehicles – not standing in line to invest in this particular technology? A number of reasons come to mind.

The first reason is that new carbon-free technologies, such as BECCS, may take several decades before they become privately profitable. This is not unique to BECCS. Offshore wind, solar power and electric vehicles have all been privately unprofitable for many years now and none of them is expected to become privately profitable in the coming decade., This means that investors in new carbon-free technologies need government support, in order to bridge these non-profitable years and to be able to invest in their development (CPB/PBL/SCP, 2014). Therefore, governments have set up incentive programmes for many of those technologies. In the Netherlands, this concerns the SDE+ programme (for renewable energy), and the tax exemptions of the electricity tax (for solar PV), and of the BPM and MRB (for electric vehicles).

In the Netherlands BECCS is, in principle, eligible for support under the SDE+ programme, but the level of support is insufficient to effectively stimulate investment. Under the SDE+ programme, reimbursements depend on the difference between the cost of renewable and fossil energy. However, the SDE+ programme does not reimburse the costs associated with CO_2 capture and storage (CCS). That incentive, theoretically, should be delivered by the Emissions Trading System. But because of the double exemption issue in the ETS directive and the too low carbon prices, the system is wholly ineffective in providing such incentives for BECCS.

Therefore, the main reason why investors have shown no interest in BECCS is that proper government support is lacking.

Replacing the current exemption under the ETS directive with a reimbursement of an emission allowance would create a level playing field for BECCS. This would mean that companies 'pay' with an emission allowance when they emit CO_2 from fossil fuels and this allowance is returned to them if and when they capture and store this CO_2.

Owners of BECCS will not need to hand over any emission allowances when they produce electricity from biomass, but they would receive a free emission allowance for every tonne of CO_2 that they store below ground. This would create the incentive for investment in this type of power plant (see Figure 3).

If, as a result of this incentive, companies would really invest in BECCS, the number of emission allowances would increase, but that would not change the amount of CO_2 that is emitted into the atmosphere. After all, although the issuance of additional allowances would lead to additional CO_2 emissions, BECCS first had to extract this CO_2 from the atmosphere. Thus, on balance, no additional CO_2 would enter the atmosphere.

However, even after adjustment of the ETS directive, power companies still have little incentive to invest in BECCS, since the advantage of such plants is that they make expensive measures elsewhere in the economy unnecessary. Most of those expensive measures, such as electric driving and energy-neutral housing, do not fall under the regime of the Emissions Trading System. Therefore, although owners of BECCS could sell their emission allowances to other companies falling under the ETS, they could not sell them to homeowners or motorists.[17]

This means that the price they would receive for their emission allowances is much lower. After all, assuming an 80% emission reduction target for 2050, selling an emission allowance to firms currently within the ETS would yield only 115 euros per tonne of CO_2, whereas including activities currently outside the ETS, the same tonne would fetch as much as 340 euros.[18] At a CO_2 price of 115 euros per tonne, investments in BECCS will be at least 80% below their efficient level.

There are, however, various ways to enable owners of BECCS to sell their emission allowances for 340 euros per tonne. The most obvious one is expanding the Emissions Trading System to all sectors, including small businesses and households. This could be done directly, by allowing small businesses and households to trade in emission allowances themselves, or indirectly by expanding the ETS to also include suppliers of energy, such as distribution companies and refineries.[19]

[17] Owners of a BECCS power plant cannot sell their emission allowances to either the natural gas supplier of homeowners or to the fuel supplier of motorists, as these companies are not included in the Emissions Trading System (ETS).
[18] These prices were calculated using the MERGE-CPB model. The number of emission allowances in the Emissions Trading System are assumed to decrease after 2021, linearly by 2.2% per year (EC, 2014). The number of allotted emission allowances does not decrease for aviation. For more details, see Bollen (2016).
[19] Currently, process emissions from refineries are included into the Emissions Trading System. However, the CO_2 encapsulated into their end-products (gasoline, diesel, etc.) is not.

Another option would be to transfer emission allowances from ETS sectors to non-ETS sectors. All these options would make climate policy within the European Union efficient, as the marginal cost of emission reductions in and outside the ETS would equal.

4 Other effects are limited

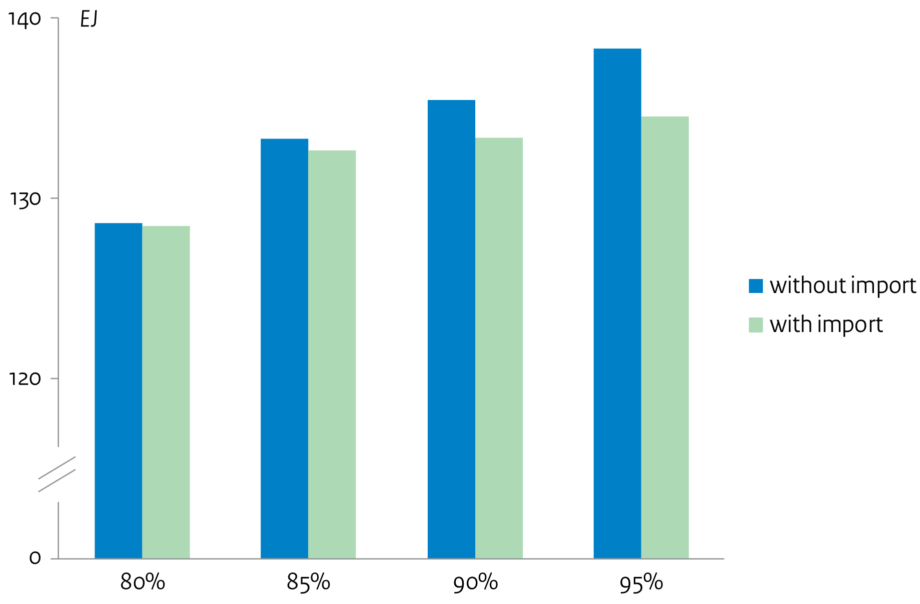
Above, we demonstrated that from an economic point of view the use of BECCS has great advantages. As a result, biomass demand might increase substantially in order to supply BECCS. This might, in turn, increase imports of biomass into Europe, thus restricting the availability of land for food production outside Europe. Poorer countries may be particularly affected, and the increase in the demand for biomass may also lead to further deforestation.[20]

Another downside of BECCS is that it may decrease the amount of biomass available for the chemical industry. Furthermore, the negative emissions from BECCS will decrease the need to reduce the use of fossil fuels, which will have a negative impact on air quality. Finally, there is some resistance within society to storing CO_2 underground due to safety issues.[21] If the application of biomass in power plants were to increase the underground storage of CO_2, this may affect public safety. This section describes how these potential downsides are either non-existent or could be easily overcome.

No negative effects on food production and deforestation

One of the main concerns regarding the use of biomass relates to food supply. Therefore, we studied the impact that the use of BECCS might have on global biomass demand.

Figure 4 Global biomass production 2050, with and without EU import restrictions

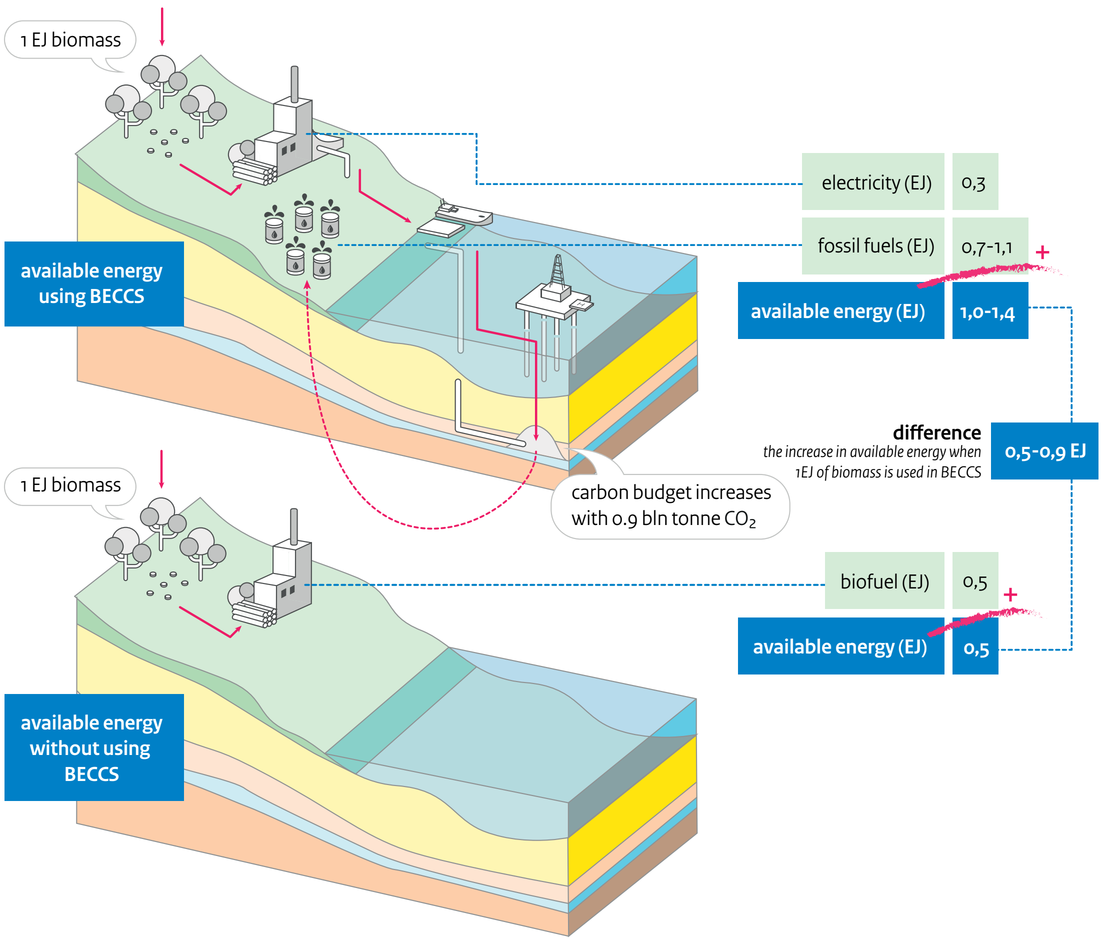


[20] See the Dutch Sustainable Biomass Commission (2015), Dutch House of Representatives (2014).
[21] https://www.rijksoverheid.nl/actueel/nieuws/2010/11/04/co2-opslagproject-barendrecht-van-de-baan.

Without BECCS, the EU will use around 9.6 EJ of biomass by 2050.[22] If the EU allows BECCS, the total import of biomass will be around 0.8 EJ under an 80% reduction target and 7.6 EJ under a 95% target. Depending on the required target, this would bring total biomass use by 2050 to 10.4 EJ and 17.2 EJ, respectively.

Rather surprisingly, biomass import into the EU would cause global demand for biomass to decrease, instead of increase (Figure 4).[23] The reason is that the demand for biomass in BECCS makes energy less scarce, because it increases the carbon budget. On the one hand, the demand for biomass increases because of BECCS. But on the other hand, the increase of the carbon budget allows for more fossil energy use, which in turn lowers the demand for renewable energy, and thus also for biomass. The net impact is a decline in the demand for biomass.

Figure 5 The effect of 1 EJ biomass on the supply of energy with and without BECCS when CO_2 emissions are kept constant



[22] If the EU does not allow biomass-imports, then land-use patterns in Asia, Africa and South America are unaffected.
[23] Even if, on a global level, there would only be 100 EJ instead of 150 EJ available in sustainable biomass, the pressure on agricultural land would be reduced through the application of biomass in CCS power plants.

Roughly speaking, the use of 1 EJ of unconverted biomass in a BECCS power plant results in around 0.3 EJ of electricity (Figure 5). Additionally, the storage of 0.9 billion tonnes of CO_2 allows the use of fossil fuels and resources in the petrochemical industry to increase by 0.7 to 1.1 EJ, respectively.[24] Thus, in total, using 1 EJ of biomass in BECCS power plants, results in 1.0 to 1.4 EJ of energy.

In contrast, without BECCS, the use of 1 EJ of unconverted biomass provides about 0.5 EJ of biofuel or resources for the petrochemical industry. Thus, the use of BECCS results in a net energy gain of around 0.5 to 0.8 EJ.

Furthermore, the increased use of fossil energy, will not lead to higher CO_2 emissions since the increased emissions from fossil energy are counterbalanced by lower (negative) emissions from biomass. On balance, this would make CO_2 emission levels more or less constant, by 2050.[25]

No negative effect on the petrochemical industry

The increased availability of fossil energy also means that the use of BECCS will not lead to shortages in high-value resources and fuels in the petrochemical, aviation and heavy transport industries. Quite the contrary, it would alleviate such shortages.

Complying with air quality standards

A disadvantage of BECCS is that air pollution increases as a result of the additional use of fossil energy. Thus, without BECCS, the average exposure of humans to particulate matter in Europe would decline by approximately 60% by 2050 under an 80% emission reduction target and by 70% under a 95% emission reduction target.[26] With BECCS, this decrease is limited to about 50%. This would mean that the air quality in 2050 would not comply with the EU air quality standard for 2030.[27]

However, the EU can quite easily comply with the 2030 air quality standards by taking additional measures.[28] The costs of such measures would be less than 1% of the increase in welfare created by using BECCS. Therefore, using biomass in this way remains a very attractive option, also from a societal perspective.

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[24] Indirect emissions released during the production of fossil fuel strongly determine the additional amount of fossil fuel that can be used on the basis of additional emission allowances. Unconventional oil (e.g. shale oil, tar sands and gas to liquids) and synthetic oil (e.g. gas to liquids and coal to liquids) have more indirect emissions than the currently more common light crude oil (Brandt and Farell, 2007). A certain amount of these indirect emissions, however, could be captured by using CCS technology during the production process.

[25] Using BECCS slightly increases the CO_2 emissions by 2050. Note that emission levels in any particular year might deviate from that year's target, due to either banking or borrowing of emission allowances.

[26] This is the average exposure of the total EU population over an entire year, in both rural and urban areas. It is lower than the measured concentration levels in so-called hotspot areas. In 2010, this average exposure equalled 10 $\mu g/m^3$. The 2030 EU target equals approximately 4 $\mu g/m^3$. For further details, see Bollen (2016).

[27] For 2030 onwards, EU policy is assumed to limit the average exposure to particulate matter to around 4 $\mu g/m^3$, due to the national emission ceilings for SO_2 (sulphur), NO_x (nitrogen), NH_3 (ammonia), and $PM_{2.5}$ (particular matter).

[28] This, among other things, concerns end-of-pipe measures, such as filters, but also shifts in the use of fossil energy.

Public safety

A final objection against using BECCS concerns the safety of CO_2 storage.[29] Possibly the simplest way of accommodating those concerns is to prohibit CO_2 storage on land. This would not affect the use of BECCS, as it remains extremely profitable, both from a private and societal perspective. Moreover, most of Europe's storage capacity is offshore.

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[29] Survey results, incidentally, indicate that the Dutch are far more positive about storing CO_2 from biomass than from fossil fuel (Mastop et al., 2014).

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T +31 88 984 60 00

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