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Biofuels and the energy transition: Green sprouts or biowashing?

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Key points :

- Biofuels come from biomass, and as such contain biogenic CO_2, while fossil fuels contain fossil CO_2
- As a result, burning biofuels does not increase the concentration of CO_2 in the atmosphere, which is why biofuels are deemed relevant to help decarbonise our economies
- However, 'bio' does not equal 'sustainable', because sourcing biomass and turning it into biofuels can have significant harmful impacts
- A careful and comprehensive lifecycle analysis is needed to assess the merits of any biofuel or biofuel project
- Two areas must be especially scrutinised: Is there competition with the food chain? And is there damage to the land and to local communities?
- We believe biofuels can be a good solution in the energy transition, but that sustainable jet fuel and biomethane have better credentials than bioethanol and biodiesel
- We suggest sustainably-minded investors could invest in this space, but selectively and after careful due diligence

As the world galvanises its efforts to reach net zero, biofuels are attracting ever increasing attention – at September's G20 summit, India's Prime Minister Narendra Modi launched the Global Biofuel Alliance in a bid to promote the use of cleaner fuel.[1]

Biofuels are essentially any fuel derived from living matter – plants, algae or animal waste. In its latest World Energy Outlook,[2] the International Energy Agency (IEA) asserts that it expects demand for liquid biofuels to increase by 2.4 to 4.2 times between 2021 and 2050, and its share of total liquid demand to grow from 2.9% to between 4.9% and 16.7%.

It further indicates that more than 80 countries have legal mandates to blend liquid biofuels with oil-based fuels, which could broaden their use further. The energy watchdog's numbers are even more impressive for biogas – gas produced by the breakdown of organic matter - and biomethane, sometimes known as renewable natural gas.

Exhibit 1 : Bioenergy demand according to the IEA's scenarios

	2021	2050		
		STEPS	APS	NZE
Total Liquid - mb/d	97	108	70	34
Liquid Biofuels - mb/b	2.2	5.3	9.2	5.7
Share of bioenergy	2.3%	4.9%	13.2%	16.7%
Multliplicator vs 2021		2.4	4.2	2.6
Total Gas - bcme	4 248	4 661	3 568	2 681
Biogas & Biomethane - bcme	35	245	339	405
Share of bioenergy	0.8%	5.3%	9.5%	15.1%
Multliplicator vs 2021		7.0	9.7	11.6

Source: IEA, AXA IM. Mb/d: Million barrels per day; bcme: Billion cubic meter equivalent. STEPS, APS and NZE are the IEA's three scenarios for future energy trends

However, the Paris-based agency is not unique in seeing a bright future for bioenergy. Most, if not all, energy transition scenarios – including those from the Intergovernmental Panel on Climate Change (IPCC) - include it as one of the primary levers to help decarbonise the global economy.

As Dr. Floor van der Hilst, winner of the first AXA IM Climate Transition Award in November 2021, asserted: "The sustainability of different biomass feedstocks is the subject of ongoing debate."[3]

In this paper, we explain why biofuels are on the energy transition map – the magic phrase is biogenic carbon dioxide (CO_2) - and briefly describe how they are produced, and why it is necessary to think in terms of lifecycle analysis. We will conclude by assessing what it all means for investors.

This note focuses on liquid biofuels - bioethanol, biodiesel, renewable diesel, and sustainable aviation fuel – and on biogas. The use of forest products and wood is a very relevant subject, as solid biomass accounts for three quarters of total bioenergy but will not be covered here.

Why are we talking about bioenergy?

Let's start with a few definitions, borrowed from the IEA, to frame the debate:

- Biomass is material which is directly or indirectly produced by photosynthesis, e.g. trees, crops, grasses, tree litter, algae, animals, manure, and waste of biological origin
- Bioenergy is renewable energy derived from biomass
- Biogenic carbon is the carbon that is contained in biomass

It would also be wise to remember that according to the IPCC's most recent work, global warming is undeniably caused by human activities that produce greenhouse gases (GHG), mostly by burning fossil fuels, and that the increase in temperature is correlated with the concentration of GHG in the atmosphere[4].

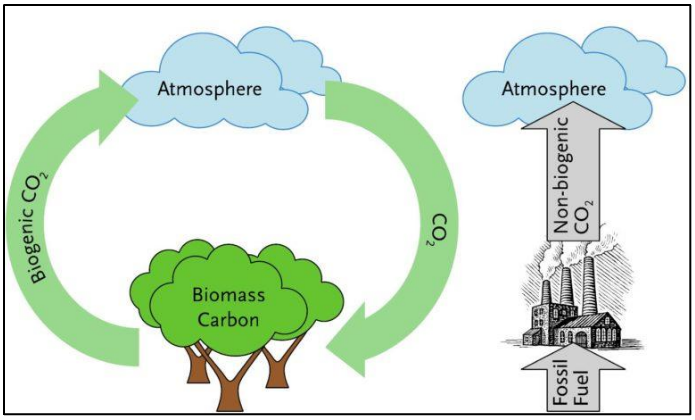
Additionally, scientists[5] distinguish between the slow carbon cycle – where the time scale is 100 to 200 million years – and the fast carbon cycle, where they talk in mere months to decades. Biomass is squarely part of the fast carbon cycle.

When biomass grows - whether it's a tree, a crop such as corn or rapeseed, or indeed any flora - it pulls CO_2 from the atmosphere through the photosynthesis process.

For this reason, burning bioenergy is akin to releasing the CO_2 back into the atmosphere it has come from, and as such is neutral in terms of climate change – the CO_2 is simply recycled.

By contrast, when fossil fuels burn, the CO_2 they contain is a net addition to the stock in the atmosphere because it was taken from underground, and it therefore contributes to global warming. Exhibit 2 illustrates the difference between biogenic CO_2 - derived from biomass – and fossil CO_2 which comes from fossil fuels.

Exhibit 2: The merry-go-round of biogenic CO_2



Source: IEA Bioenergy

It is essential to understand the consumption of bioenergy releases CO_2, and in most cases as much as the consumption of fossil fuels. The difference solely comes from the origin of this CO_2.

From a more formal perspective, the GHG Protocol – an organisation that provides widely recognised guidelines for greenhouse gas accounting and reporting - recommends that "companies shall separately account for and report biogenic and non-biogenic CO_2 emissions, and biogenic and non-biogenic CO_2 removals (if applicable)"[6]. It is an acknowledgment of the difference in nature between these two categories of CO_2.

To sum up, the convention is that the CO_2 emitted from burning biofuels does not count. This is the fundamental reason for biofuels to be considered a legitimate lever in the energy transition.

A family portrait of biofuels

	Feedstock	Main end-use	Features
Bioethanol	Mostly startch and sugar	Automotive	Can be blended with gasoline up to 10%; 15% for some vehicles
Biodiesel	Vegetal oils and animal fat, virgin or used	Heavy duty transportation (trucks, buses etc)	Produced through the FAME (fatty acid methyl esters) process. Blending limited to 5% (USA) and 7% (Europe)
Renewable Diesel			Produced through the HVO (hydrotreatment of vegetable oils or animal fat) process. Chemically identic to fossil diesel so no blending limit
Sustainable Aviation Fuel		Air transport	Produced through the Hydroprocessed Easters and Fatty Acids (HEFA) process Maximum blend 50%
Biomethane	Crops, vegetal residues, animal manure, landfill gase and water treatment waste	Power generation, home heating, industrial furnaces	Perfect substitute for natural gas as it is the exact same molecules (CH_4)

Liquid biofuels production

Depending on the nature of the initial biomass, biofuels are qualified as being first, second or third generation:

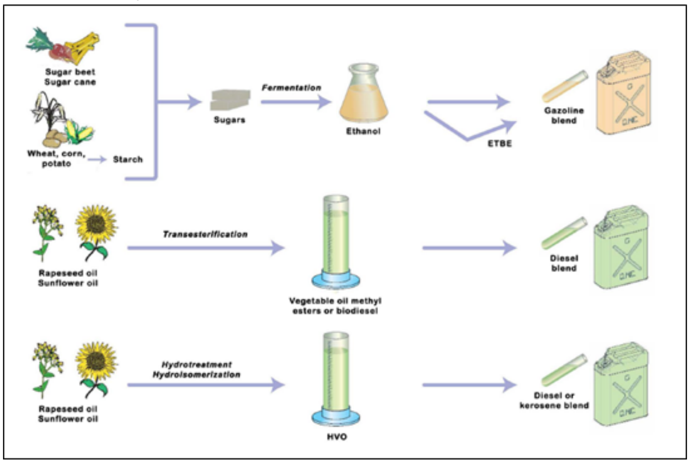
1. First generation: Biofuels from edible crop (e.g. palm oil, corn, or sugarcane) produced on arable land
2. Second generation: Biofuels from non-edible crop (e.g. switchgrass) and waste (e.g. crop residues, used cooking oil, tallow)
3. Third generation: Biofuels from algae and forestry and agricultural residues

In practice, first generation biofuels account for more than 95% of production and third generation is still in development. Second and third generation biofuels are often bundled together under the name of advanced biofuels.

The industrial pathways follow a similar logic for all liquid biofuels, although sugar and starch end up as gasoline, and vegetal oil and fats, as diesel and jet fuel:

- Biomass collection
- Extraction: The sugar/starch/oil is extracted from the biomass
- Conversion: The extracted material is converted into biofuel through various industrial and chemical processes (such as fermentation, transesterification or hydroisomerization)
- Purification: The obtained biofuel undergoes purification to remove impurities
- Blending/final product: The purified biofuel is blended with conventional fuel or directly used when possible

Exhibit 3: Liquid biofuels schematic



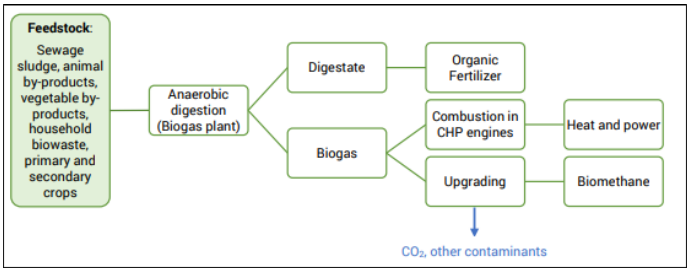
Source: IFP Energies Nouvelles, retrieved in July 2023

Biogas and biomethane production

Biogas and biomethane, at the risk of stating the obvious, are gaseous biofuels. Biogas typically contains 50% to 60% of biomethane and 40% to 50% of CO_2. Exhibit 4 illustrates the production process.

Biogas can be consumed directly, to produce electricity and heat, or can be further purified or upgraded into biomethane.

Exhibit 4: The production of biomethan through anaerobic digestion and upgrading



Source: ETIP Bioenergy, 2020. CHP: Combined Heat & Power

It is also worth noting the digestate, i.e. the solid leftover from the fermentation process, can be used as an organic nitrogen-rich fertiliser, displacing carbon intensive synthetic fertilisers. Other pathways exist (e.g. pyro-gasification - heating waste in a low-oxygen environment to produce biogas) but are much less developed.

Natural fermentation occurs for organic waste in landfills. So-called landfill gases can contain up to 50% of biomethane. They can be collected and either used as such or upgraded into biomethane.

As a side note, waste management companies are responsible for those landfill gases (they account for most of their direct emissions) and collecting them to, at minima, flare them is an essential building block of their sustainability strategy. Depending on the relative value of power and biomethane, an operator will choose to use biogas directly or upgrade it into biomethane. Given the many strategic decisions - such as REPowerEU in the European Union, or financial support, including Renewable Identification Number (RIN) certificates in the US (used to track renewable fuels) - upgrading biogas into biomethane is increasingly favoured.

Sustainability and biofuels: All about feedstock

We explained that bioenergy is part of the debate thanks to biogenic CO_2. However, generally, any time 'bio' is attached to a word, a red flag should immediately be raised, and careful analysis must follow. In bioenergy, the 'bio' prefix comes from the 'bio' in biomass. Just because it is 'bio' and comes from nature does not mean that a product or solution always has a positive environmental impact.

For instance, if forests have been cut down or if there is a massive use of pesticides, the final tally can be negative from a broad environmental perspective. In other words, biowashing is a real risk.

As such, it is important to understand the origin of the biomass and whether it has been sustainably procured. Bioenergy is relevant because biogenic CO_2 does not count, but if there is too much damage prior to the combustion phase, then the benefits can be more than erased and biofuels could ultimately generate negative externalities.

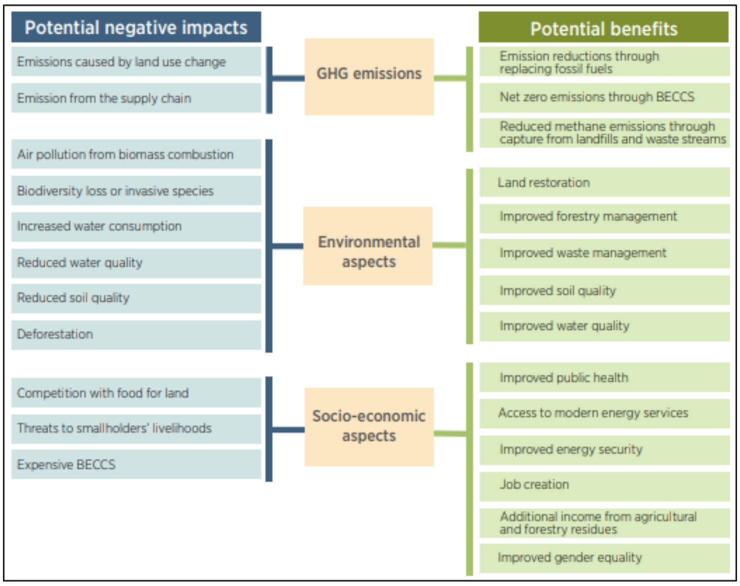
This is bringing us back to a common thread in all energy transition debates: the need for a lifecycle analysis (LCA) to properly understand the environmental impact – including GHG emissions - from cradle to combustion.

The International Organization for Standardization (ISO) defines an LCA as the "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle". Such a LCA is a way to assess those impacts along the value chain, for instance related to land use change or the application of pesticides we mentioned earlier.

While this is not a discovery and is already commonly used – as illustrated by International Air Transport Association (IATA) guidelines about sustainable aviation fuel (SAF)7 or the logical existence of ISO standards, it is essential to think systematically in terms of LCA.

An LCA can go beyond environmental impacts and can be used to assess the broader impacts of a product, notably on the social front, as highlighted by Exhibit 5.

Exhibit 5: The broad impact of the use of biomass



Source: Bioenegy for the Energy Transition, IRENA, 2022

The objective of this note is to focus on environmental issues. While many elements could be highlighted, there are four we believe are the most critical.

- Competition with the food chain. This is a genuine concern for first generation biofuels as they are made from edible crops. For instance, more than half of the world's bioethanol comes from the US – where it is produced from corn (see the following focus box) and about 30% comes from Brazil, where it is made from sugarcane. The land dedicated to both crops could be dedicated to food or feed or could be left unused for nature to thrive on its own

For second generation biofuels, the question is different as the feedstock is not edible. The debate shifts to the impact of growing the specific crops – for instance, do they require chemical inputs, or do they draw resources from the soil – and to previous use and benefits, if any, of the waste streams.

This is a not a theoretical concern and it can lead to real world decisions, as happened in China in 2022 when it said it would strictly control corn ethanol production due to crop maize shortages.[8]

- Impact on land use and land use change. Deforestation is now a well-documented and recognised source of both GHG emissions and biodiversity damage. Similarly, changing the use of non-forest land to grow crops can release carbon stored in the soil

- Use of fertilisers and pesticides. This goes beyond crops for biofuels, but overapplication of fertilisers and pesticides has dire consequences for the environment, be it for excess volumes of fertilisers ending up in waterways or pesticides reducing biodiversity

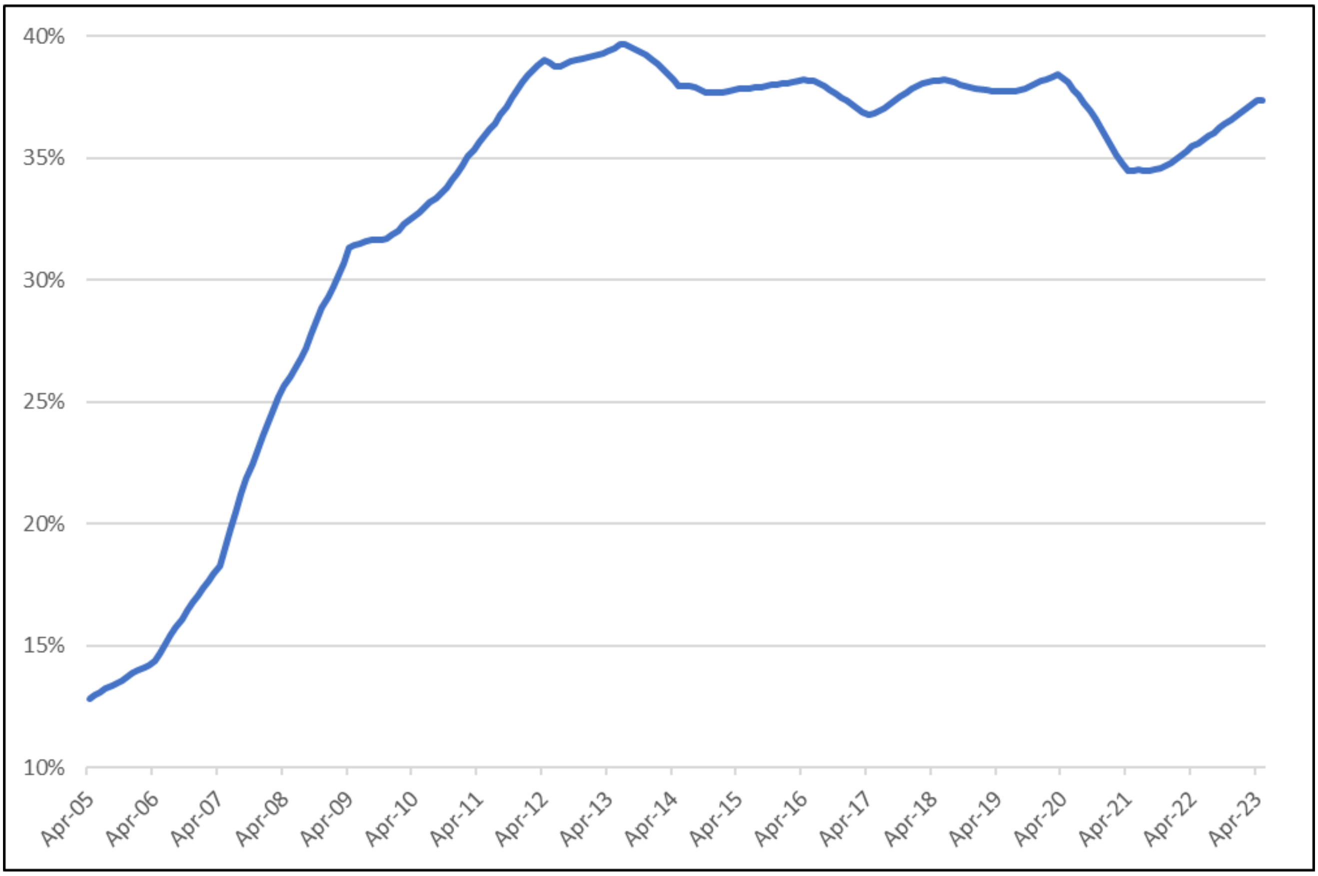
- Water consumption. 70% of freshwater use comes from agriculture and animal breeding[9]. As for fertilisers and pesticides, this is a broad subject, and the question is whether the water is consumed for the right reasons

It is important to bear in mind that questions relating to growing biomass are by and large the same whether the final use is for food, energy, or materials. It is about finding the right balance between society's needs and sustainable development.

Focus Box: Corn in the USA

The introduction of the first Renewable Fuel Standard in the US in 2005 triggered a strong boom for the corn-to-ethanol industry. Within a few years, nearly all gasoline transitioned to include 10% of ethanol and the standard gasoline blend became E10 gasoline. Over the same time, the share of corn used to produce ethanol went from 12% to between 35% and 40% of total corn production, a threefold increase, while corn production *only* increased by 35%.

Exhibit 6: Share of US corn turned into ethanol



Source: USDA, AXA IM

The US corn industry is built on intense mechanisation, significant use of fertilisers and pesticides, and genetically modified (GMO) seeds. According to the United States Department of Agriculture (USDA)[1], 34.5 million hectares were used to grow corn in the US in 2022, meaning that more than 12 million hectares were dedicated to ethanol production. By contrast, the entire EU corn acreage was less than 10 million hectares. This raises the question of the impact of such a massive activity.

A recent study[1] concluded that the full impact of corn-based ethanol is at least 24% more carbon-intensive than gasoline, contradicting the conclusions of another study[1], where ethanol is presented as at least 39% less carbon-intensive than gasoline.
This shows that LCA is a robust tool but there can be strong methodological differences amongst studies, in this case related to carbon storage by crops, change in acreage, and use of fertilisers.

This also shows that there is a debate that goes beyond technical factors and belongs to the societal and political field.

Are biofuels and biogas the right decarbonisation solution?

A common point for any instrument in the decarbonisation toolbox is to carefully assess and understand its relative merits compared to other tools. For biomass and bioenergy, the point is to assess where they are the most useful and the most relevant. Just because a tool could be used, it does not mean that it should be, most notably if there is another and superior alternative. This is a similar logic to the one applying to hydrogen: The H_2 molecule can technically be used in many applications to help decarbonise the economy, but it is the best tool to do so for a limited number of those applications.[10]

Here, again, LCA is a necessary methodology as it permits to properly compare different decarbonisation levers, and help selecting the best suited for a given end-use.

We believe that the question we asked deserves different answers depending on the product we look at:

- Ethanol: As it is blended with gasoline, ethanol is used to reduce the carbon intensity of automobiles. As such, it competes with electric vehicles (EVs). When comparing the sustainability merits of ethanol and EVs, we believe that the rising penetration of EVs, coupled with the greening of power generation, make electrification superior to ethanol. Ethanol is a way to dilute gasoline, but at the cost of locking massive amounts of land. As ethanol is mostly made from corn and sugarcane, it is also a direct competition with the food and feed value chain

- Biodiesel and renewable diesel: The conclusion reached for ethanol equally applies to biodiesel. To dilute crude oil-based diesel with largely vegetal oil-based products, rainforests have been cleared in Asia to grow mostly palm trees, which creates significant biodiversity issues. This is the root driver for AXA IM's deforestation policy. As for cars, electrification is gaining ground for diesel vehicles – trucks, buses, and offroad equipment – and is a superior solution. Renewable diesel, when it is made from waste and residues, appears however to be a good solution

- SAF: We believe the situation is very different for air travel than for ground travel. The solutions to wean planes off kerosene, i.e. jet fuel, are far from mature and are likely to take at least a decade if not more before they're ready. As such, SAF is a solution available today which can help in reducing emissions, even though the scale of current production and planned developments is clearly insufficient.[11] As for diesel, a waste and residue-based process is more desirable. In addition, SAF has been shown to emit much less sulphur oxides (SOx) – which are the source of acid rains – and small-size particulates (i.e. soot) than fossil-based jet fuel[12]. Those lower soot emissions lead to less condensation trails – or contrails[13] – high up in the atmosphere, which is another climate-positive factor. This should however not push aside the debate on air travel and its overall contribution to global warming

- Biomethane: Methane and biomethane are chemically identical. From a customer perspective, there is no technical impediment to switching from one to the other; it is very akin to electricity, where a fossil-based electron is the same as a renewable-based electron. For applications and usages where alternative energy sources are not available, biomethane is a legitimate solution, for instance for very high heat industrial processes such as flat glass making.

Those views are based on technical and environmental elements, and not on costs. End-users will of course factor in the relative costs of different energy sources and balance the usually higher biofuel costs with the benefits of using biofuels for their CO_2 footprint.

Playing devil's advocate: Holes and loopholes

While we contend that biofuels have a role to play, it is easy enough to take the opposite view and poke holes into the positive case for biofuels. As Institute for Progress article, for instance, focuses on US biofuel policy, and usefully highlights the pros and cons, and the complexity, of the debate.[14]

Affecting food prices. Through biofuels, and mostly ethanol, some crops have become intertwined with crude oil; corn in the US is a perfect example. A high oil price can attract a larger conversion of the crop into an energy product, at the detriment of its use as feed or food, impacting both availability and price. It is not a systematic case and is context specific but has been demonstrated in certain situations[15].

CO_2 duration mismatch. A core argument in favour of biofuels is that the emitted CO_2 does not count because it is biogenic and short cycle. This assumes that this released CO_2 is reabsorbed by vegetation within one year or in the next growing season. This might be true for annual crops such as corn or sugarcane, but what if some of the biomass takes longer to grow? There could be a mismatch between the time it takes for the CO_2 to be absorbed and its release in one go. To use financial lingo, there is a potential duration mismatch or an asset-liability management problem.

Here again, it matters to have good supply chain visibility, in this case of biomass growing patterns.

This is clearly a more burning question for forestry management, even though a central point is the overall shape of harvesting/consuming that matters rather than an individual forest or land patch analysis.

LCA: Model vs. reality: We have insisted on the absolute need for careful LCA. It is simple but not unfair to counter that a model is not the reality. Even the best analytical tools cannot reflect the diversity of feedstocks, operational practices, and geographies. LCAs are necessary, but on-the-ground inspections and controls are needed, and it is not possible to verify everything.

Conflict of use: Biomass is presented as a solution to decarbonise our economic system, as a raw material, a source of molecules, or as bioenergy. Many stakeholders and many industries are hence laying claims on biomass. Not everyone and not every use can be satisfied.

It is important to make sure the best use is prioritised, and that biomass is leveraged where it is the most impactful in the fight against climate change. In some cases, this can mean not using it.

Stressing the land: Directly linked to the previous point, stretching nature to produce more and more biomass can quickly be counterproductive in terms of biodiversity and ecosystem resilience.

Could the non-counting of biogenic CO_2 be threatened? We believe this is a question worth pondering. Burning SAF or biomethane emits CO_2. It is biogenic CO_2, but it remains the same greenhouse gas that the modern industrial economy has pumped into the atmosphere for more than 150 years. Given the continuous increase in CO_2 emissions and the lack of ambitious enough policies and actions, could the "climate neutrality" of biogenic CO_2 be reconsidered? In a warmer world, the nature of CO_2 could be disregarded. This could be even more the case in situations where there are alternative solutions to biofuels, such as electric mobility.

We do not have any specific insight for such a question, but if global warming is not abated enough, i.e. if emissions are not reduced enough, we suspect that even biogenic CO_2 could be challenged.

What is the angle for investors?

Biofuels are part of the solution if and only if they are sustainable across the entire value chain. A sustainably minded investor must hence ensure than investee companies involved in the biofuel value chain are focusing on sustainability. For this paper, we define the biofuel value chain as such: Feedstock production and/or collection; technologies and equipment providers; biofuel producers and fuel retailers.

Practically, the most important subject is related to the feedstock i.e. the biomass, and whether it has been sourced in a sustainable way. To a large extent, this is a similar approach to the vigilance investors ought to have when they invest in the food value chain[16]. Traceability is hence a most critical area.

The main concern relates to first generation biofuels as they directly compete with the food chain. As such, favouring companies focusing on biofuels made from waste and residues appears a logical conclusion. For companies producing ethanol or biodiesel made from food crops, more scrutiny is warranted.

In their analysis and engagement with biofuel-exposed companies, investors should make sure that there is no competition with the food chain and that there is no undue damage to the environment. The companies should report on those subjects and disclose their policies and actions.

In addition, we suggest asking the following questions to tackle those points:

1. What is the original feedstock?
2. Is the feedstock linked to deforestation or land use change?
3. Where is the feedstock sourced?
4. For cultivated crops, what are the agricultural practices?
5. Is there competition with the food chain?

With thanks to Louise Héraud for her additional reporting and research

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