SustainaWeekly

The Green Bubble and other scenarios

- **Economist: The NGFS recently published a concept note on short-term climate scenarios, including additional colour on financial and short-term effects. In comparison with earlier scenarios, they are more suited for macroeconomic forecasting on the one hand, and stress testing on the other. As well as scenarios that have similar elements to the past, such as Sudden wake-up Call and Highway to Paris, the Green Bubble is a relatively new one.**

- **Strategist: There are two types of risks associated with biodiversity. Physical risks stem from the loss of biodiversity and transition risks stem from regulations/policies introduced by regulators to mitigate biodiversity loss risks. Several central banks have calculated their national financial institutions exposure to biodiversity risks. Results are discouraging, but regulators have already a few regulations in place to try to mitigate the loss.**

- **Sectors: Fossil fuels could be replaced by less polluting synthetic fuel alternatives. Renewable diesel and bio-diesel can replace petroleum diesel. E-methanol, bio-methanol or solar methanol can replace methanol and green hydrogen can replace blue and grey hydrogen. However, these more sustainable fuels are expensive, most have limited availability and have numerous other challenges.**

- **ESG in figures: In a regular section of our weekly, we present a chart book on some of the key indicators for ESG financing and the energy transition.**

The Network for Greening the Financial Sector (NGFS, a group of central banks and supervisors sharing best practices in environmental and climate risk management in the financial sector) recently published a concept note on short-term climate scenarios, including additional colour on financial and short-term effects. In this week's SustainaWeekly we first explore the scenarios and key innovations presented compared to what has been done previously. In a separate note, we provide a brief description of what biodiversity is, what are biodiversity-related risks, how these risks are measured, and what regulations/policies are currently in place. A longer thematic on this topic will be published soon. In our final note, we analyse to what extent synthetic fuels can replace fossil fuels, taking in some of current challenges.

Enjoy the read and, as always, let us know if you have any feedback!

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NGFS scenarios enriched with short-term and financial narrative

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- **The NGFS recently published a concept note on short-term climate scenarios, including additional colour on financial and short-term effects**
- **In comparison with earlier scenarios, they are more suited for the main purposes of macroeconomic forecasting on the one hand, and stress testing on the other**
- **The shorter time horizon and inclusion of financial shocks could help to construct plausible scenarios, combining elements of a number of those scenarios, for instance for the purposes of stress testing**

New NGFS scenarios approach has been published

The Network for Greening the Financial Sector (NGFS, a group of central banks and supervisors sharing best practices in environmental and climate risk management in the financial sector) recently published a concept note on short-term climate scenarios, including additional colour on financial and short-term effects. These scenarios have not yet been quantified: the approach and scenarios have been published in a concept note. Still, the note is very interesting as it takes steps towards making climate scenarios specifically suitable for the main purposes: macroeconomic forecasting on the one hand, and stress testing on the other. Due to the short term nature of the scenarios, they can account for shocks that have a short-term impact and subside in the medium term (such as shorter-lived confidence/financial market effects). Including these types of shocks is a step towards more realistic scenarios, and a shift away from stylised examples.

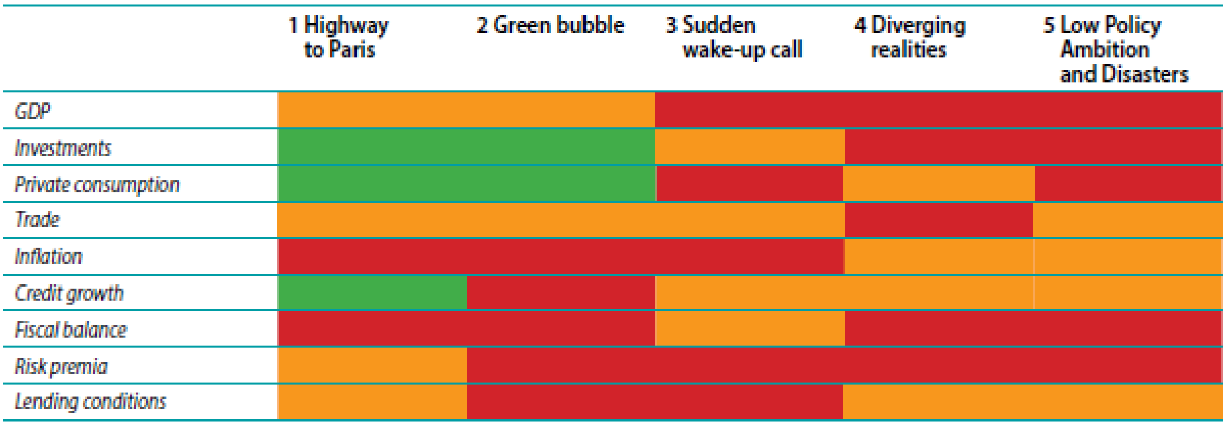
Setup of the scenarios and salient points

In the new setup, each scenario has climate shocks (policy or physical) and macro financial shocks. There is an emphasis on adverse scenarios given their use to test the resilience of economic and financial systems.

There are 3 example pathways in which net zero is reached. Firstly, the **"Highway to Paris**" scenario, which is closest to the "orderly net zero" in which the carbon tax increase is expected and a boom in green investment is financed by carbon taxation. The negative shock from the carbon tax and the positive shock from the investment boom lead to an on balance favourable economic outcome. The **"Green Bubble"** disorderly scenario is one where net zero is reached, but with subsidies rather than taxes incentivising the green shift (comparable to the US Inflation Reduction Act, all carrots, no sticks). This leads to a glut of private investment and an increase in debt. In this example pathway, the green investment bubble bursts at some point, leading to a confidence crisis and increased risk premia. The **"Sudden wake-up call"** disorderly scenario reflects a world of widespread climate ignorance, which is challenged by a sudden change in policy preferences, triggered by for instance a surprise election result favouring green parties or a natural disaster. This leads governments to hastily implement a stringent mitigation pathway, leading to a speedy re-allocation of capital from polluting to green sectors. The sudden and unanticipated nature of climate policies leads to financial turmoil and a crisis of confidence.

There are two example pathways in which Net Zero is not reached. In the "**Diverging Realities"** disorderly scenario some countries do transition quickly but others do not, so that the global context is one of an ineffective transition in which net zero is not reached. As a result, the countries that do transition are presented with strong transition, as well as physical risks. Such a scenario would be the result of for instance lack of finance in emerging markets and developing economies. As disaster-prone areas suffer from the fallout, supply chains are disrupted and economic activity stalls. Migration flows to less affected areas. Risk premia rise as the most plausible scenario shifts. The hot house world scenario "**Low policy ambition and disasters"** is about physical risk manifesting in the short term. This is not so much related to the emissions pathway in the scenario, as physical risk is dependent on emissions of previous years (lagged response). The focus in this scenario is on: "How to model/transmit physical risk shocks into the economy?". In this scenario, natural disasters lead to a spike in risk premia while supply chains are disrupted, real estate prices drop in affected areas and households consume less and save more. An important point in scenarios with high physical risk is the response of (re) insurance sectors, as increased insurance premiums can lead to chilling effects on economic activity and delayed or abandoned investment due to higher costs, or even unavailability of, insurance (see for instance our note here on this topic).

Sources of stress for each scenario



Note: Colours indicate the levels of stress. Red refers to high, orange to medium and green to low levels of stress.

Source: NGFS

Incorporating acute physical shocks

To incorporate the impact of (acute) physical shocks on the economy in a short-term climate scenario, there are a few options. The first option is that of implementing a specific physical shock. Depending on the nature and location of this shock this could be for example via sectoral added value, supply of production factors, production or services disruption. The risk and severity of a shock can be assessed with Natural Catastrophe models, that take into account the latest science on the characteristics of extreme weather events and the impact of climate change more broadly. As most severe natural disasters are expected to occur beyond the short-term time horizon, it may be useful to incorporate future shocks (that are due to current lack of abatement) forward in time.

Secondly, acute physical shocks can be incorporated via the effects of an increased risk of natural disasters. For instance, the sudden reassessment of the likelihood of acute physical risk in the future can manifest itself as a shock to expectations on any of the above-mentioned variables and reduced investment spending and increased uncertainty. Such a confidence shock could be captured via a shock to expectations. An uncertainty shock could be captured via an increase in the equity and/or sovereign risk premium.

Energy and critical materials prices

Other relevant shocks for the transmission into the macrofinancial environment are shocks to energy and critical materials prices. With regards to energy prices, the NGFS notes that it is useful to take into account the feedback loop between carbon and energy prices. First, carbon prices are likely to trigger an energy price shock due to the direct impact of carbon prices on the price of fossil fuels, which are still an important source of energy. These higher prices then incentivise the switch to clean energy. However, if fossil fuel prices are already high for a non-carbon price related reason, carbon prices need not be as high to incentivise a GHG reduction. Still, in this case the increased fossil fuel revenues flow to fossil fuel producers, while, on the other hand, carbon revenues flow to the public sector which may then chose to recycle them back into the economy, turn them into incentives for greening. Thus, the GHG reduction would not be as permanent as one that is caused by emission-reducing innovation and the economic impact would be less favourable.

Given that the path to net zero is paved with wind turbines, solar panels, and batteries, scarcity of critical materials, such as lithium, cobalt and nickel needed for these goods, such as lithium, cobalt, and nickel, are a real risk (see **here** a note on this). Scarcity of critical materials could be captured by a proxy variable such as the cost of capital for green technologies. Another option might be to take into account price spikes on final goods relying on these critical materials.

Other main determinants of economic impact

The impact of climate policy is determined by their stringency (obviously) but other important drivers are the elasticity of substitution between fossil fuels and other forms of energy (very different per sector); and what the authorities do with the carbon revenues (the “recycling option”). The more revenue is rebated to households, the less demand falls and therefore the more prices will rise in response to the negative supply shock stemming from climate policies. Usually, governments care more about perceptions of fairness and political acceptability of their policies than the inflationary impacts. It is this likely that a politically feasible climate policy would entail some form of revenue recycling to households.

These elements make it possible to construct more realistic scenarios

These NGFS scenario still represent stylised examples to some extent. Still, we think that plausible scenarios will combine elements of a number of those scenarios. When looking at this mix of elements, it is clear that the mix will be different per country. There are some clear frontrunners, such as for instance the EU, and clear laggards such as for instance Russia. This important point is taken into account explicitly in the “Diverging Realities” scenario, where countries in transition are faced with both transition and physical risk.

One of the hottest topics of the decade: biodiversity

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- **Biodiversity stands for biological diversity. The loss of biodiversity translates into the loss of services provided by ecosystems to the real economy**
- **There are two types of risks associated with biodiversity: physical and transitions risks**
- **Physical risks stem from the loss of biodiversity (e.g. disappearance of animal pollinators), and transition risks stem from regulations/policies introduced by regulators to mitigate biodiversity loss risks (e.g. the introduction of a tax on fertilizers)**
- **The ENCORE database provides scores for each sector and sub-sector on their exposure to biodiversity risks**
- **De Nederlandsche Bank, the Banque de France and the Bank of England used the above database to calculate their national financial institutions exposure to biodiversity risks**
- **Results are discouraging, but regulators have already a few regulations in place to mitigate biodiversity loss risks**

Life as we know it might well be at risk. Approximately one million species are currently on the brink of extinction, and, according to the Organization for Economic, Co-operation and Development (OECD), the world already lost an estimated EUR 3.5 - 18.5 trillion per year in ecosystem services from 1997 to 2011 owing to land-cover change. But what does this mean for biodiversity? Or for firms and individuals that highly depend on the viability and longevity of biodiversity?

That is what national central banks, like the Bank of England (BoE), the Banque de France, and De Nederlandsche Bank, have been trying to answer in recent years. More recently, the European Central Bank (ECB) also published a written statement (**see here**) revealing that it would publish a report in 2023 showing how much the euro area economy and financial sector are exposed to risks related to ecosystem services. This report is yet to be published.

This Sustainaweekly is only the first of a few pieces about the topic that we will publish through to the end of this year. In this first piece, we provide a brief description of what biodiversity is, what are biodiversity-related risks, how these risks are measured, and what regulations / policies are currently in place. In our soon to-be published ESG Outlook for 2024, we will calculate each sector's exposure to biodiversity risks, and assess the exposure of 17 European banks considering their loan book and each sector's biodiversity score. Moreover, a final piece will follow focusing on investors, and what is the perception of investors regarding biodiversity.

But first, what is biodiversity?

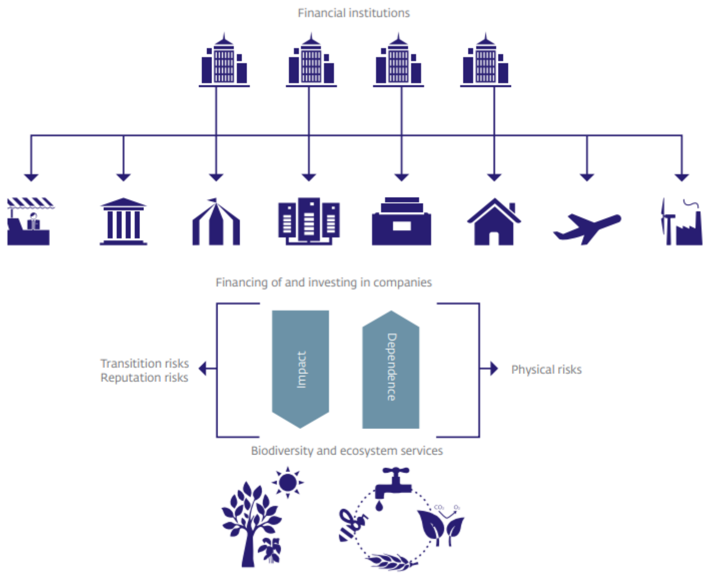
Biodiversity stands for biological diversity, and captures the variety and variability of life on Earth. Furthermore, ecosystems – which entail all the living things in a particular area as well as the non-living things – are built upon the basis of biodiversity. As such, the loss of biodiversity in a certain ecosystem translates into a loss of the services that ecosystems provide to the real economy. There are four different types of ecosystem services :

1. **Provisioning** services of tangible products, such as food, timber and cotton;
2. **Regulating** services, such as animal pollination, air and water treatment, and soil fertility;
3. **Cultural** services, which are ecosystems contributions to sectors like education, recreation, and tourism;
4. **Supporting** services, such as the nutrient cycle, soil conservation and habitat creation.

The diversity of species is of crucial importance for ensuring that ecosystems are stable and function well over the longer term. Such that, the loss of biodiversity would translate into economic consequences for a company that can be severe, and hard to predict.

Despite the complexity of calculating a company's exposure to biodiversity, regulators have been developing tools and methodologies in order to evaluate the exposure of firms to biodiversity loss, and, ultimately, to quantify financial institutions' exposure to these companies. Below, we plot a graph depicting the relationship between ecosystem services, non-financial institutions, and financial institutions.

Relationship between financial sector, economy, biodiversity and ecosystem services



Source: DNB.

What are biodiversity-related risks?

The first challenge is to define the risks that companies are facing. Risks can either be physical, stemming from the loss of biodiversity, like the extinction of bees, and ultimately in the disappearance of animal pollination. Or can be transition risks, stemming from regulations adopted by governments to avoid biodiversity loss, like the introduction of taxes on fertilizers.

Furthermore, these risks will have different consequences throughout the value chain. For instance, the loss of crop production can have a negative impact on the profitability of primary producers, but it will also affect raw material prices that food processors face. In the above-mentioned methodologies, regulators only accounted for first-order dependencies, given how complex it would be to capture all ecosystem services involved in a company's operations. As such, the risks set out are most likely an underestimation.

How to quantify physical and transition risks?

The physical risks related to biodiversity are captured by the dependence of a company on a certain ecosystem service (i.e. a business which is highly dependent on ecosystem services is more likely to be directly affected by a physical shock). Regarding transition risks, these are captured by how much a company impacts the ecosystem, i.e. a business with a significant negative impact on biodiversity has a higher chance of being affected by biodiversity policies (transition shock) than a business with a low impact.

But how could a financial institution start to map the dependence and impact of the companies in its loan book? The ENCORE database provides these dependence and impact scores by sector and sub-industry regarding 21 ecosystem services. The score ranges between *very high materiality* to *very low materiality*. When provided with the scores, one is able to calculate the dependence and impact a company has on biodiversity based on the number of products and the location of the company's production assets. Finally, with the help of balance sheet data from financial institutions, it is possible to determine the extent of lending to, and investment in, sectors with products that are dependent on a certain ecosystem or that extensively impact a certain ecosystem.

Results from central banks

According to Banque de France, considering Scope 1 dependencies to ecosystem services, i.e. the dependencies of direct operations, 42% of the value of loans and investments held by French financial institutions comes from borrowers that are highly or very highly dependent on at least one ecosystem service. According to DNB's report, this number is 36% for Dutch financial institutions. Both reports indicate that the highest dependence is on the ecosystems that provide groundwater and surface water.

The Bank of England has also conducted a similar analysis considering the UK economy, and they found that over half (52%) of UK GDP and nearly three quarters (72%) of the stock of UK lending exhibits dependence on ecosystem services – levels that suggest elevated vulnerabilities.

In terms of transition risk, the biodiversity footprint of Dutch financial institutions is comparable with the loss of over 58.000km^2 of pristine nature. This is an area more than 1.7 times the land surface of the Netherlands. In the case of France, the accumulated terrestrial biodiversity footprint of the French financial system is comparable to the loss of at least 130.000km^2 of pristine nature.

What are regulators doing?

Even tough the numbers are discouraging, regulators worldwide are aware of the urgency of the topic, and have adopted policies / regulations to mitigate biodiversity loss risks. According to the OECD PINE database (see **here**), the most common ones are **taxes on pesticides, fertilizers, forest products and timber harvests**. Currently, there are 234 biodiversity-relevant taxes in place across 62 OECD countries, which generate USD 7.7bn in revenue every year. Even though it is already a considerable amount, it only represents 0.92% of all environmentally-related tax revenue.

Furthermore, there are also **biodiversity-related tradable permits**. The latter include individual transferable quotas (ITQs) for fisheries, tradable development rights, and tradable hunting rights. These quotas limit the total amount of a natural resource that can be exploited. Currently, 39 schemes are in place across 26 OECD countries.

Moreover, biodiversity-related **subsidies** are also another form of regulation in place. Examples of these subsidies include environmentally-motivated subsidies that target forest management and reforestation, organic or environmentally-friendly agriculture, pesticide free cultivation, and land conservation. There are currently 163 environmentally-motivated subsidies across 28 countries, as reported in the PINE database.

Finally, the European Commission (EC) also published its **EU Biodiversity strategy for 2030**, in which it pledges that by 2030, at least 30% of the land and 30% of the sea should by protected in the EU. This is a minimum of an extra 4% for land and 19% for sea areas as compared to 2020. Moreover, it pledged to reverse the decline of pollinators, to reduce the use of pesticides by at least 50%, to have at least 25% of agricultural land under organic farming management, and to plant three billion new trees in the EU, in full respect of ecological principles.

Synthetic fuels to the rescue?

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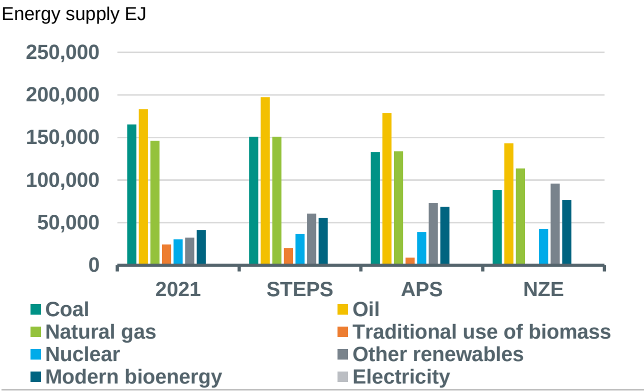
- **Fossil fuels have 80% share in the global energy supply**
- **To decarbonize, these fossil fuels could be replaced by less polluting alternatives**
- **Renewable diesel and bio-diesel can replace petroleum diesel…**
- **…e-methanol, bio-methanol or solar methanol can replace methanol and…**
- **…green hydrogen can replace blue and grey hydrogen**
- **But these more sustainable fuels are expensive, most have limited availability and have numerous other challenges**

Introduction

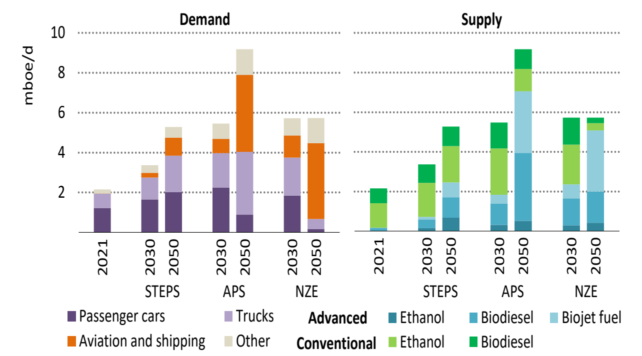
Fossil fuels play a crucial role in our economy. According to the IEA global energy supply for coal, natural gas and oil took a share of close to 80% in 2021 (see graph below). To reach net-zero by 2050, we need to reduce our dependency on burning fossil fuels. Renewables and bio-energy will play a crucial role. The main problem with renewables is intermittency, so they come and go and patterns can be difficult to predict. We focussed on renewables and how to tackle the intermittency challenge in earlier publications on solar, wind, heating and battery technologies. In this report we focus on fuels that can replace fossil fuels but that emit less or no CO2. The graph on the left below shows the share of modern bio-energy in 2021 (6.6%) and the role the IEA expects it to play in the different scenarios in 2030.

Global energy supply for different scenarios 2030



Source: International Energy Agency (2022), World Energy Outlook 2022, IEA, Paris, STEPS = Stated policies, APS = Announced Pledges scenarios, NZE = Net Zero Emissions

Liquid biofuel demand and supply by scenario



Source: International Energy Agency (2022), World Energy Outlook 2022, IEA, Paris, STEPS = Stated policies, APS = Announced Pledges scenarios, NZE = Net Zero Emissions

Replacing fossil fuels by more sustainable fuels

Replacing fossil fuels by fuels that emit less or no emissions seem easy. But in reality it is a complicated endeavour. For a start there are many different types of more sustainable fuels (more on this below). Every fuels has its own characteristics and therefore different fuels would be suitable for different applications. Fuels can for example be compared on the basis of their emission intensity, their energy density, storage needs, safety, costs and fuel infrastructure and production. Different fuels have different energy density levels, which can be measured in terms of equivalent energy released through combustion. Energy density can be measured in gravimetric energy density (per unit of mass) or volumetric energy density (per unit of volume). Gravimetric energy density is relevant when comparing the energy efficiency of fuels. At the same time, volumetric energy density is relevant when comparing transportation modes as storage space (fuel tank) must be present to carry the fuel propelling a vehicle. The higher the energy density, the higher the fuel quality, which is inversely proportional to its chemical complexity. In the tables later in the text we compare different fuels by type.

Moreover, to replace fossil fuels by more sustainable equivalents, changes need to be made to for example engines or the infrastructure and storage. Furthermore, the supply, production and price of more sustainable fuels are less favourable compared to fossil fuels and this will take time to change. The production of synthetic fuels need large amounts of green electricity and feedstock and there is often competition for these sources. In some cases the technology is not commercially available yet. So production needs to increase and prices needs to come down. Despite this more sustainable fuels will have a larger role to play to achieve a net zero economy globally by 2050.These fuels are also called synthetic fuels.

What are synthetic fuels?
Synthetic fuels are liquid fuels that have the same properties as fossil fuels but are produced artificially. Synthetic fuels can be blended with fossil fuels or replace the fossil fuel in internal combustion engines. These synthetic fuels are used for different purposes and different sectors. There are three types of synthetic fuels and the way they are produced makes them distinctive (source **Synhelion**).

- Biomass-to-liquid/gas produces biofuels (any fuel that is derived from biomass) such as renewable diesel/hydrotreated vegetable oil (HVO) and Sustainable Aviation Fuel (SAF)
- Power-to-liquid/gas produces e-fuels (electro fuels) such as e-methane, e-kerosine, e-methanol and hydrogen.
- Sun-to-liquid/gas produces solar fuels such as hydrogen, ammonia (source **energy.gov**)

Bio-fuels and bio-mass
Bio-fuels can be produced by agricultural waste, food waste, manure and sewage. There are liquid and solid bio-fuels. Examples of liquid bio-fuels are bio-gas, bio-methane, bio-LPG. Charcoal, biochar and biofuel pellets are examples of solid bio-fuels. The bio-fuel production is categorized into four generations based on the type of feedstock used. First generation bio-fuels primarily utilize crops that are high in sugar, starch, or oil content. Second generation bio-fuels are derived from lignocellulosic biomass. This can be from agricultural residue, waste or dedicated biomass plants. Third generation bio-fuels are produced from microalgae such as bio-diesel and seaweed, mainly for bio-ethanol. Fourth generation bio-fuels are generated from genetically modified microalgae. The graphs above on the right show demand and supply of liquid biofuels in 2030 and 2050 in different scenarios.

Burning **sustainably-resourced wood** is carbon neutral as the CO2 emissions emitted during burning are equal to trapped emissions during the growth of the trees. **Bio-gas** is produced by the breakdown of organic matter. It is a mixture of methane, hydrogen and carbon dioxide. The methane content of biogas typically ranges from 45-74% by volume, with most of the remainder being CO2 (**www.iea.org**). The precise composition of bio-gas depends on the type of feedstock and the production pathways. **Bio-methane** is a bio-gas from which the carbon dioxide, hydrogen sulfide and water have been removed. It Is also known as renewable natural gas. As a result of the purification process, the bio-methane has the same characteristics as natural gas. So bio-methane is the purified form of raw bio-gas. The combustion of these creates CO2 emissions, but since the bio-gas is derived from plants (which remove CO2 from the atmosphere) the CO2 emissions are generally considered carbon neutral.

Bio-methanol is produced by fermenting biomass such as wood or agricultural waste using microorganisms that are cable of producing methanol. Bio-methanol is simply methanol produced from biomass and other non-fossil sources. Methanol, the alcohol with the simplest chemical structure (CH3OH), is a colourless, tasteless liquid with a faint odour. Methanol (including bio and e-methanol) is seen as a promising alternative fuel for maritime shipping. Dimethyl ether or **DME** is produced from methanol by simple dehydration. It is a gas that can be liquified at moderate pressure. DME is a diesel fuel substitute but it can also replace LPG in applications such as heating and cooking.

Bio-LPG is produced from renewable sources including biological oil and fats and the fermentation of glucose by microorganism. It has a lower carbon footprint than conventional LPG (up to 80% lower). It is identical in its chemical structure to conventional LPG. It can be used as drop-in fuel and in existing gas boilers.

Bio-diesel is a renewable fuel that can be manufactured from vegetable oils, animal fats or recycled cooking grease for use in diesel vehicles. It can be produced through four different methods: oil-blends, micro-emulsion, pyrolysis and transesterification. Transesterification is an eco-friendly chemical process in which the fatty acids react with the alcohol to produce biodiesel and glycerol. **Renewable diesel** is a fuel made from fats and oils and is processed to be chemically the same as petroleum diesel. It can be used as a replacement fuel or blended with any amount of petroleum diesel. The production process is different than with biodiesel but it is coming from similar feedstock. It has a better resilience to bacterial growth in comparison to biodiesel. Therefore a better solution for longer and standby applications. It has a lower density and energy content than diesel. Renewable diesel meets the conventional specification allowing it to be used in existing infrastructure and diesel engines. Hydrogenated Vegetable Oil (HVO) is made from a variety of vegetable oils and fats containing triglycerides and fatty acids. Another name is hydro-processes esters and fatty acids (HEFA). It is also called renewable diesel. Sustainable aviation fuel or **SAF** is made from non-petroleum feedstocks. It can be blended at different levels with limits from 10%-50%, depending on the feedstock and how the fuel is produced. **Ethanol** is a renewable fuel made from corn and other plant materials. It is used in various applications such as cleaning agents and transportation fuel.

Biomass-to-liquid/gas fuels

Fuels		Energy density Gravimetric	Energy density Volumetric	Possible use	Pros	Cons
Bio-gas	Gas		16-28 MJ/m3	Heating, electricity generation, cooking		
Biomassa	Solid	17.1 MJ/kg	21.8 MJ/m3	Heating, electricity generation, cooking	Renewable Waste reduction	High costs Space requirements
Bio-methanol	Liquid		16 MJ/l	Maritime shipping Production bio-diesel Production DME	Lower carbon footprint Production does not involve experimental technologies Hydrogen carrier Easy to store Minor modification to existing infrastructure	Low production, higher costs Methods for efficient conversion in research stage Highly flammable, corrosive to some metals, toxic Competition for renewable feedstock Lower volumetric energy density
Bio-methane = renewable natural gas	Gas		36 MJ/m3	Replace compressed natural gas	Lower emissions Identical to natural gas, same infrastructure	Unpleasant odours It is highly explosive Need of large quantities of organic waste
Bio-DME	Gas	28.0 MJ/kg	19.2 MJ/m3	Propoane supplement Bottled cooking gas As transportation fuel on the rise	Low emissions High energy density Retrofitting engines is relatively simple	Production from synthesis gas under development Cannot be blended with fossil diesel Lower volumetric energy content than diesel
Renewable diesel or HVO	Liquid	44 MJ/kg	34.8 MJ/l	Transportation fuel	Diesel engine compatability Existing diesel infrastructure Performs better than FAME in lower temp Reduces the carbon intensity on average by 65% (NREL	
Bio-diesel or FAME	Liquid		32.7 MJ/l	Transportation fuel Heating Cooking	100% biodiesel are 74% lower than petroleum diesel en Existing infrastructure Existing engine technology	Lower energy content Low outside temprature could cause solidifying Higher than 7% adjustments of engines Quality depends on properties of feedstock used
SAF	Liquid	42.8 MJ/kg		Aviation fuel	Diesel engine compatability Existing diesel infrastructure SAF has potential to reduce emissions by 80% Mature technology	Feedstock availability Vulnerability to supply chain shocks More expensive than jet fuel
Ethanol	Liquid	19.9 MJ/kg	21 MJ/l	Medicinal Alcohol beverages Cleaning agent Transportation fuel and fuel additive	Emisisons are reduced on average by 40% (corn-based Higher power and performance than gasoline	Use of food crops Some upgrade of equipment

Source: IEA, NREL, KPMG, energy.gov, eFuel Alliance, IRENA, and various scientific reports

Power to liquid fuels

Next to bio-fuels and bio-mass also power-to-liquid fuels could be used to replace fossil fuels. These are synthetically produced liquid hydrocarbon. Renewable energy is the key energy source, and water and carbon dioxide are the main resources. First renewable electricity is generated, which then drives an electrolyser that splits water into hydrogen and oxygen. Next, the hydrogen is mixed with carbon dioxide and turned into syngas via the reverse water gas shift (RWGS) reaction – a process that is conducted at high temperatures and driven by electricity. The mobility sector will likely use a lot of these fuels in the future for the hard to abate sectors. E-methanol is methanol produced using renewable electricity.

Power-to-liquid/gas fuels

Fuels		Energy density Gravimetric	Energy density Volumetric	Possible use	Pros	Cons
eFuels general			10 kWh/l	Transportation fuel Heating	Transported at room temperature and pressure Negligible carbon footprint Drop-in capability Existing infrastructure	Expensive Low production Battery electric may be a better option
e-methanol	Liquid	19.9 MJ/kg	15.6 MJ/l	Transportation fuel Production bio-diesel Production DME	Negligible carbon footprint Pre-established and mature processes Hydrogen carrier Can be used in fuel cell Minor modification to existing infrastructure	Low production, expensive Methods for efficient conversion in research stage Highly flammable, corrosive to some metals, toxic Competition for renewable feedstock Lower volumetric energy density
e-methane	Liquid	50 MJ/kg	20.8 MJ/l	Replace compressed natural gas		
e-kerosene	Liquid	45.7 MJ/kg	40 MJ/l	Aviation fuel Heating	Turbines and storage compatible	Energy intensive to make Not large scale yet
e-ammonia	Liquid	18.6 MJ/kg	11.5 GJ/m3	Agricultural fertilizer Transportation fuel Hydrogen carrier	It has higher volumetric density than liquid hydrogen Not explosive No carbon emissions	Ammonia slip Toxic Expensive
e-hydrogen	Liquid	120 MJ/kg	8.5 MJ/m3	Transportation fuel Oil refining Production of fertilizer Storage fuel	No carbon emissions	Low volumetric energy density Adjustments to storage and infrastructure Applications can be in infancy, not large scale yet Expensive

Source: IEA, NREL, KPMG, energy.gov, eFuel Alliance, IRENA, and various scientific reports

Sun-to liquid fuels or solar fuels

Solar fuels are synthetic chemical fuels produced from solar energy. Solar fuels are fuels made from common substances like water and carbon dioxide using the energy of sunlight. Options for solar fuels include making hydrogen as a fuel by using solar energy to split water, or producing alcohols such as ethanol and methanol by using solar energy to reduce carbon dioxide with hydrogen, or creating less-conventional fuels such as ammonia by using solar energy to reduce nitrogen with hydrogen (source: **energy.gov**).

Sun-to-liquid/gas fuels or solar fuels

Fuels		Energy density Gravimetric	Energy density Volumetric	Possible use	Pros	Cons
Hydrogen	Liquid	120 MJ/kg	8.5 MJ/m3	Transportation fuel Storage fuel Production of fertilizers	No carbon emissions	Low volumetric energy density Adjustments to storage and infrastructure Applications can be in infancy, not large scale yet Expensive
Ammonia	Liquid	18.6 MJ/kg	11.5 GJ/m3	Transportation fuel Fertilizer	It has higher volumetric density than liquid hydrogen Not explosive No carbon emissions	Ammonia slip Toxic Expensive
Solar kerosene	Liquid	45.7 MJ/kg	40 MJ/l	Aviation fuel Heating	Turbines and storage compatible	Energy intensive to make Not large scale yet
Solar methanol	Liquid	19.9 MJ/kg	15.6 MJ/l	Transportation fuel Production bio-diesel Production DME	Negligible carbon footprint Pre-established and mature processes Hydrogen carrier Can be used in fuel cell Minor modification to existing infrastructure	Low production, expensive Methods for efficient conversion in research stage Highly flammable, corrosive to some metals, toxic Competition for renewable feedstock Lower volumetric energy density
Solar ethanol	Liquid	19.9 MJ/kg	21 MJ/l	Medicinal Alcohol beverages Cleaning agent Transportation fuel and fuel additive	Net zero carbon emissions Higher power and performance than gasoline Divert no land away from food production	Some upgrade of equipment Technology is at laboratory scale

Source: IEA, NREL, KPMG, energy.gov, eFuel Alliance, IRENA, and various scientific reports

Fuel additive and improved fuel

Next to replacing a fossil fuel by a more sustainable fuel, the fossil fuel can also be improved to reduce energy use and hence emissions. This can be done by adding fuel additives. Fuel additives are chemicals that can be added to gasoline to improve vehicle performance or help maintain systems. However, some additives could damage the electronics or the engine. There is also an improved fuel. For example Change XL. Change XL add enzymes to a conventional fuel. These enzymes break down long and complex molecular chains in the fuels and saturate the fuel mixture with oxygen. They break down the (condensed) water present in fuel and prevents problems with bacteria, moulds and yeasts by eliminating and dissolving them in the fuel. This results in a more stable, homogeneous fuel. The enzymes continue to work actively throughout the fuel chain. Change XL claims to reduce emissions by 10% and fuel savings of up to 10%. This improved fuel can be used in the existing infrastructure.

Emissions

Low carbon fuels

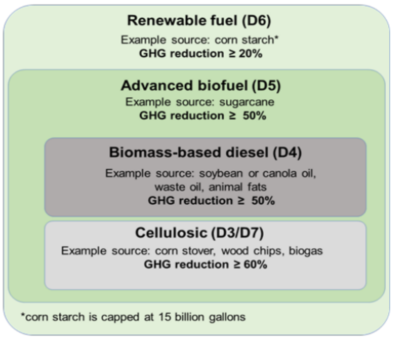
Are synthetic fuels low carbon, carbon-neutral or zero-carbon fuels? Low carbon fuels emit less carbon than fossil fuels. Renewable diesel, bio-diesel, hydrogen/methanol/ammonia when produced using fossil fuels with carbon capture and storage are examples of low carbon fuels. Renewable diesel's CO2 emissions are highly dependent on the feedstock used. Often, this results in life-cycle emissions above zero. The higher the blend-in percentage, the higher the CO2 reduction. The National Renewable Energy Laboratory (NREL) indicates that renewable diesel reduces the carbon intensity level on average by 65%. According to the NREL pure bio diesel (100%) reduces carbon dioxide emissions by more than 75% compared to petroleum diesel. The graph above shows emissions reductions of renewable fuel produced in the US.

Carbon neutral fuels

Carbon neutral fuels are fuels that do not increase or decrease the amount of carbon in the atmosphere through their life-cycle. Power-to-liquid fuels e-methanol and e-kerosine are carbon neutral fuels. They are considered carbon neutral if renewable resources are used in the production process and the carbon captured from the atmosphere is later released back into the air.

US renewable fuel production 2018 and emission reductions

U.S. fuel production by RIN type	million gallons	%
D6 Renewable fuel (-20% GHG)		86%
ethanol	14,954	
biodiesel	332	
D4 Biomass-based diesel (-50% GHG)		12%
biodiesel	1,854	
renewable diesel	282	
renewable jet	2	
D5 Advanced Biofuels (-50% GHG)		0.4%
ethanol	25	
naphtha	21	
Renewable diesel	24	
other	4	
D3/D7 Cellulosic (-60% GHG)		1.6%
ethanol	7	
natural gas (compressed)	213	
natural gas (liquified)	55	



https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rins-generated-transactions

Figure 4. U.S. renewable fuel production in 2018 (U.S. EPA 2019)

Note: RIN = renewable identification number

Source: www.epa.gov

Zero-carbon fuels

Zero-carbon fuels are fuels that do not release carbon at the time of usage. For example hydrogen when produced by electrolysis and renewable electricity and ammonia when produced by renewable electricity and green hydrogen as the source are zero-carbon fuels.

Current challenges in replacing fossil fuels with synthetic fuels

To replace fossil fuels by synthetic fuels is a complicated endeavour. There are several options. First, replace a more polluting fuel by a less polluting fuel such as the use of LNG, methanol, ammonia or hydrogen in maritime shipping. To do this, energy density, retrofitting of engines and infrastructure, safety of the fuel, production and price need to be taken into account.

Second, an existing fossil fuel can be replaced by the same fuel with a more sustainable footprint. For example bio-methanol or e-methanol can replace methanol, renewable diesel or bio-diesel can replace conventional diesel, e-hydrogen and solar hydrogen could replace grey or blue hydrogen, solar ethanol could replace ethanol in the future, bio-methane could replace natural gas and bio-LPG conventional LPG. So there are enough options. The choice to switch to the more sustainable fuel depends on the price, availability and emission reduction potential. We give three examples. We start with diesel, bio-diesel and renewable diesel. They can be used in internal combustion engines of vehicles and they have different emission levels as indicated in the biofuels table above. These more sustainable diesels can be blended with petroleum diesel. Switching from petroleum diesel to bio-diesel or renewable diesel becomes attractive if the price gaps between the diesel fuels narrow or move in favour of the more sustainable diesels. Below an overview of the price levels of transport fuels at the end of July in the US. At the end of July bio-diesel (100%) was considerably more expensive than petroleum diesel while renewable diesel was cheaper (other data source though).

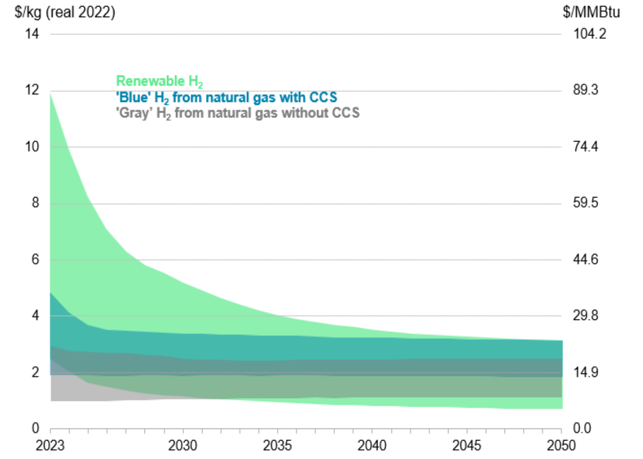
Prices of diesel alternatives end July 2023

	End of July 2023
Gasoline	USD 3.59/gallon
Diesel	USD 3.88/gallon
Bio-diesel B20 (20% bio-diesel, 80% petroleum diesel)	USD 3.77/gallon
Bio-diesel B99/B100 (pure bio-diesel)	USD 4.53/gallon
Renewable diesel (clear)	USD 3.73/gallon
Ethanol E85 (85% ethanol fuel blend, 15% gasoline)	USD 2.95/gallon
LPG	USD 3.25/gallon

Source: US Department of Energy, Bloomberg

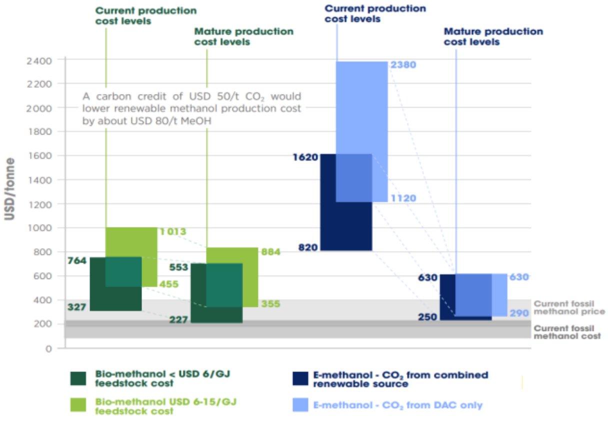
We also have taken a look at hydrogen. Hydrogen could be an important energy carrier for the transportation sector. Among other challenges, green hydrogen is also very expensive compared to blue hydrogen (with carbon capture and storage) or grey hydrogen (without carbon capture and storage). The graph below on the left shows the different levels of levelized costs for green, blue and grey hydrogen. For green hydrogen to become a viable option from cost point of view the costs need to decline substantially.

Levelized Costs of Hydrogen



Source: Bloomberg BNEF

Current & future production costs bio-and e-methanol



Notes: MeOH = methanol. Costs do not incorporate any carbon credit that might be available. Current fossil methanol cost and price are from coal and natural gas feedstock in 2020. Exchange rate used in this figure is USD 1 = EUR 0.9.

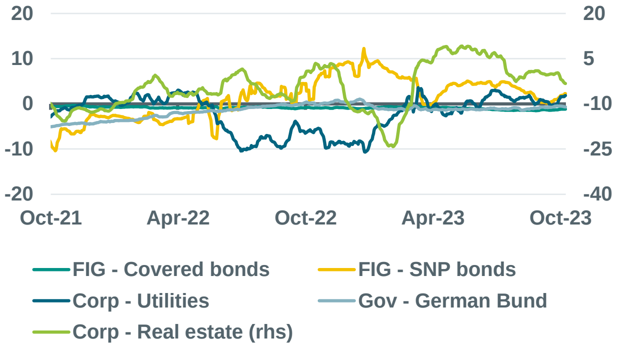
Source: IRENA

Methanol is another fuel that could play an important role in decarbonizing the mobility sector with a focus on maritime shipping. Currently methanol trades at USD 313/metric tonne. According to a report from the Methanol Institute and IRENA (**Innovation outlook renewable methanol**) the current production cost of e-methanol is estimated to be in the range USD 800-1.600/metric tonne assuming CO2 is sourced from BECCS (Bioenergy with carbon capture and storage) at a cost of USD 10-50/tonne. If CO2 is obtained by DAC (Direct Air Capture), where costs are currently USD 300- 600/tonne, then e-methanol production costs would be in the range USD 1.200-2.400/ metric tonne. Bio-methanol costs USD 700-900/metric tonne. The graph above on the right shows the difference in costs to produce. To make synthetic fuels a viable solution from price point of view, prices have to come down significantly as the examples above show and prices for fossil fuels need to increase which will most likely happen due to ETS 1 and 2.

ESG in figures

ABN AMRO Secondary Greenium Indicator

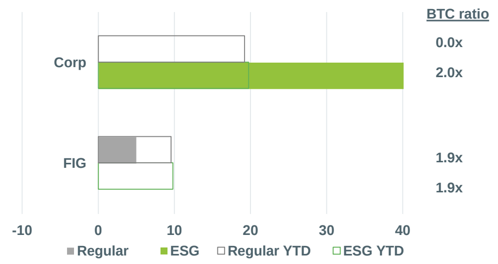
Delta (green I-spread – regular I-spread)



Note: Secondary Greenium indicator for Corp and FIG considers at least five pairs of bonds from the same issuer and same maturity year (except for Corp real estate, where only 3 pairs were identified). German Bund takes into account the 2030s and 2031s green and regular bonds. Delta refers to the 5-day moving average between green and regular I-spread. Source: Bloomberg, ABN AMRO Group Economics

ABN AMRO Weekly Primary Greenium Indicator

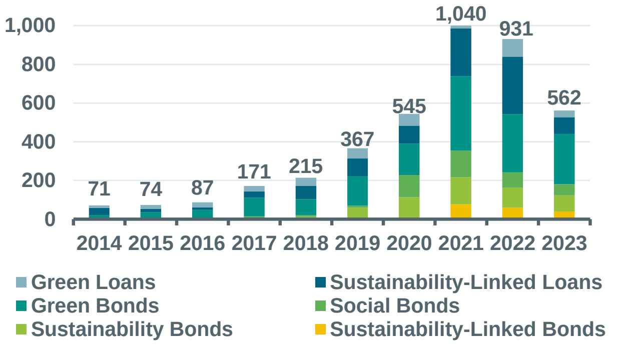
NIP in bps



Note: Data until 19-10-23. BTC = Bid-to-cover orderbook ratio. Source: Bloomberg, ABN AMRO Group Economics

Sustainable debt market overview

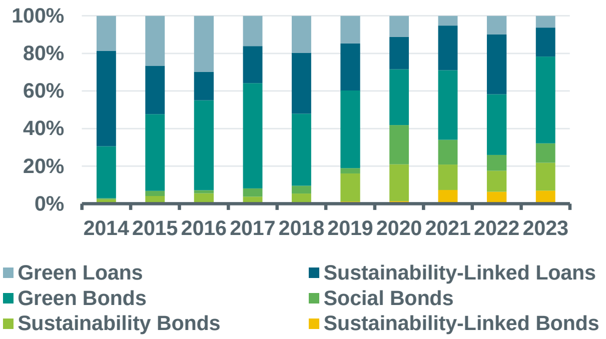
EUR bn



Source: Bloomberg, ABN AMRO Group Economics

Breakdown of sustainable debt by type

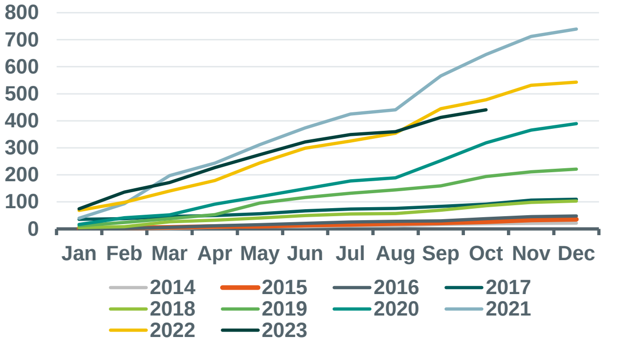
% of total



Source: Bloomberg, ABN AMRO Group Economics

YTD ESG bond issuance

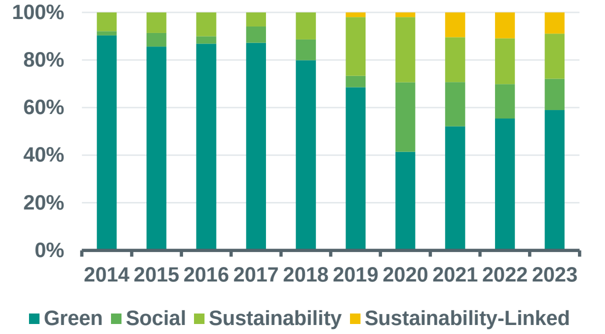
EUR bn (cumulative)



Source: Bloomberg, ABN AMRO Group Economics

Breakdown of ESG bond issuance by type

% of total

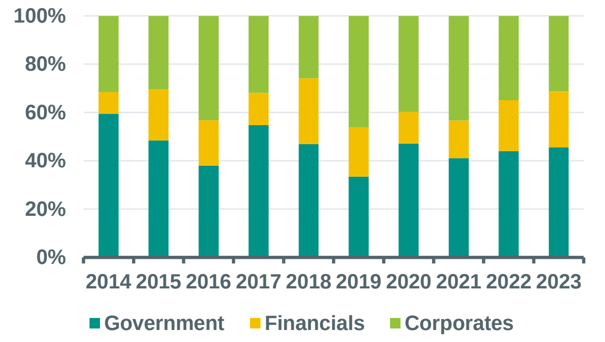


Source: Bloomberg, ABN AMRO Group Economics

Figures hereby presented take into account only issuances larger than EUR 250m and in the following currencies: EUR, USD and GBP.

Breakdown of ESG bond issuance by sector

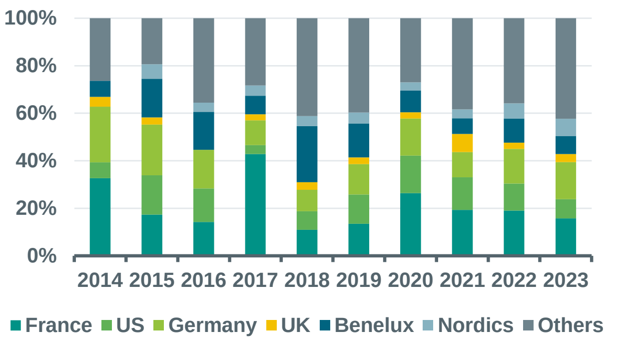
% of total



Source: Bloomberg, ABN AMRO Group Economics

Breakdown of ESG bond issuance by country

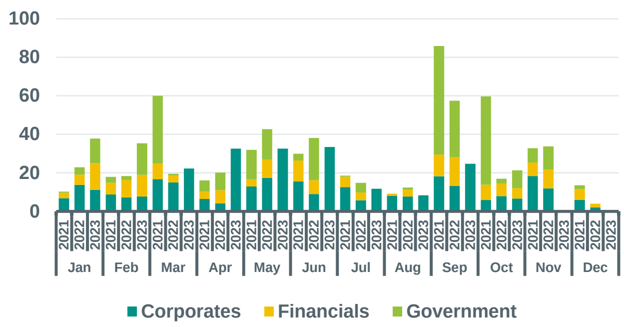
% of total



Source: Bloomberg, ABN AMRO Group Economics

Monthly Green Bonds issuance by sector

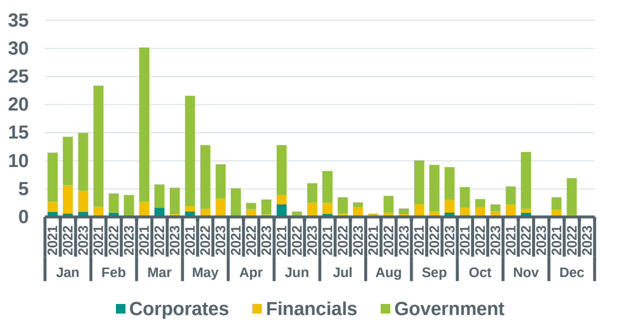
EUR bn



Source: Bloomberg, ABN AMRO Group Economics

Monthly Social Bonds issuance by sector

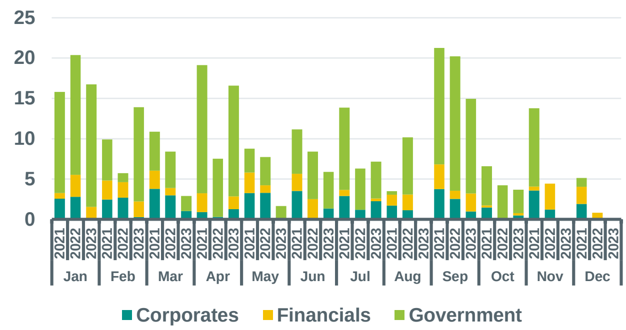
EUR bn



Source: Bloomberg, ABN AMRO Group Economics

Monthly Sustainability Bonds issuance by sector

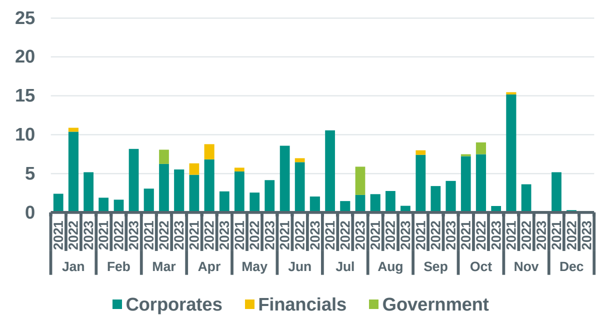
EUR bn



Source: Bloomberg, ABN AMRO Group Economics

Monthly Sust.-Linked Bonds issuance by sector

EUR bn



Source: Bloomberg, ABN AMRO Group Economics

Figures hereby presented take into account only issuances larger than EUR 250m and in the following currencies: EUR, USD and GBP.

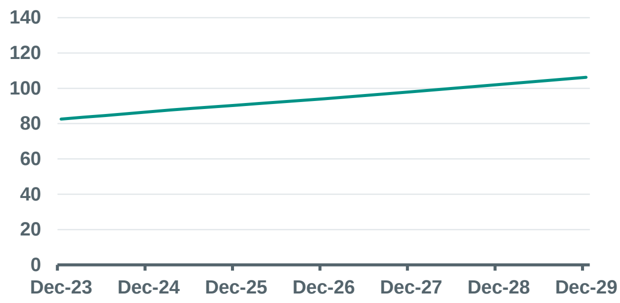
Carbon contract current prices (EU Allowance)

EUR/MT

Source: Bloomberg, ABN AMRO Group Economics

Carbon contract futures curve (EU Allowance)

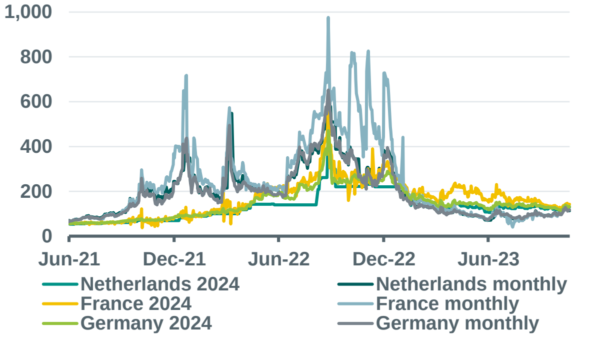
EUR/MT



Source: Bloomberg, ABN AMRO Group Economics

Electricity power prices (monthly & cal+1 contracts)

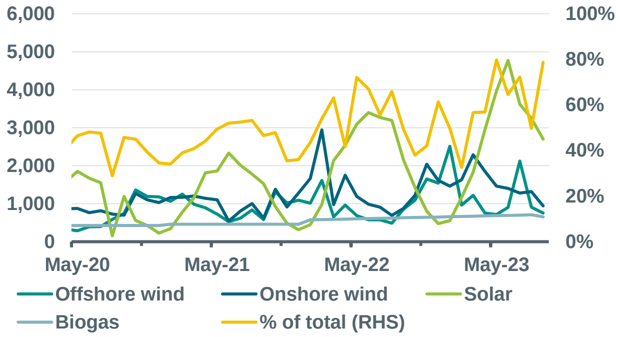
EUR/MWh



Source: Bloomberg, ABN AMRO Group Economics. Note: 2024 contracts refer to cal+1

Electricity generation from renewable sources (NL)

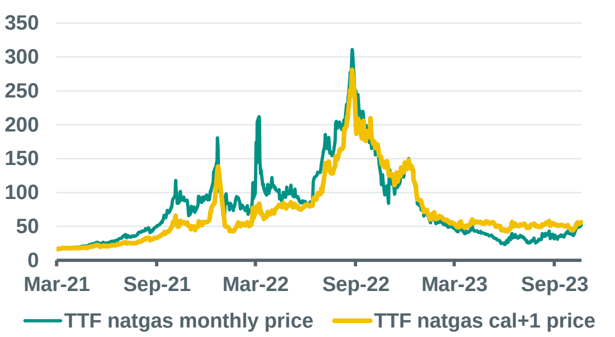
GW % of total



Source: Energieopwek (Klimaat-akkoord), ABN AMRO Group Economics

TTF Natgas prices

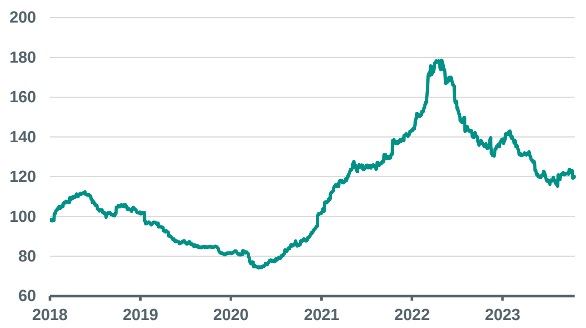
EUR/MWh



Source: Bloomberg, ABN AMRO Group Economics

Transition Commodities Price Index

Index (Jan. 2018=100)



Note: Average price trend of 'transition' commodities, such as: corn, sugar, aluminium, copper, nickel, zinc, cobalt, lead, lithium, manganese, gallium, indium, tellurium, steel, steel scrap, chromium, vanadium, molybdenum, silver and titanium. Source: Refinitiv, ABN AMRO Group Economics