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A Lloyd's emerging risk report

Below 2°C

Insurance for a low carbon economy

Sector deep dives

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Key contacts

Trevor Maynard
Head of Innovation
trevor.maynard@lloyds.com

Oliver Walker
Natural Resources practice lead
oliver.walker@vivideconomics.com

For general enquiries about this report and Lloyd's work on innovation, please contact innovation@lloyds.com

Research project team

- Dr Jason Eis, Executive Director, Vivid Economics
- Dr Oliver Walker, Principal, Vivid Economics
- Justine Schäfer, Senior Economist, Vivid Economics
- Shyamal Patel, Senior Economist, Vivid Economics
- Aaron Tam, Analyst, Vivid Economics
- Dr Swenja Surminski, Head of Adaptation Research, Grantham Research Institute at the London School of Economics
- Dr Joana Setzer, Research Fellow, Grantham Research Institute at the London School of Economics

Lloyd's project team

- Dr Trevor Maynard, Innovation
- Anna Bordon, Innovation
- Pauline Giorgini, Innovation
- Linda Miller, Brand & Communication
- Charlotte Walkling, Brand & Communication
- Michaele Hawkins, Responsible Business
- Nathan Hambrook-Skinner, External Communications
- Flemmich Webb, External Communications
- Emma Watkins, Risk Aggregation
- Emma Allen, Digital Communications
- Ian Shelley, Class of Business
- Xochitl Rodriguez, Class of Business

Lloyd's market

- Jim Lye, Antares
- Alex Hindson, Argo Group
- Ahad Khalid, AXA XL
- Peter Welton, AXA XL
- Kristian Jones, Beazley
- Emma Whiteacre, Beazley
- Alex Dunn, Chubb
- Dorothee Prunier, Chubb
- James Fryer, CNA Hardy
- Conor Husbands, Hiscox
- Lucy Hensher, Hiscox
- Frances Loring, Hiscox
- Ngozi Emeagi, MS Amlin

Industry experts

- Dr Nishatabbas Rehmatulla, UMAS
- Dr Sophie Parker, UMAS

Further thanks go to the sector experts who wish to remain anonymous.

Contents

Coal

Coal

Transition related opportunities and challenges for insurers in the coal sector stem from four key trends: steep declines in demand, the retrofitting of generation assets to biomass, the potential deployment of CCS technologies, and growth in climate related litigation.

- Challenges reflect the shrinking size of the sector, with a rapid decline in coal use by 2030 and an associated likelihood of asset stranding, and increasing reputational difficulties for insurers seeking to offer insurance to coal miners and generators. Long-term risks associated with CCS facilities are significant but remain poorly understood, representing a barrier to the provision of insurance for this emerging sector.
- Opportunities nonetheless exist in the provision of liability insurance against physical damage cases and in supporting the sector's adoption of biomass in generation, where there is an appetite to insure against supply chain risks, and of CCS, where the transfer of technology risk can attract lower cost project finance.

> *Demand in the coal sector is estimated to fall by at least 70% under the 2°C compliant scenarios by 2030. (Vivid Economics, 2019).*

Transition impact on sector

Demand in the coal sector is estimated to fall by at least 70% under the 2°C compliant scenarios by 2030 compared to the reference scenario, which result in significant asset stranding. Modelling results from the Net-Zero Toolkit indicate that coal sector firm count could be 46% (61%) by 2030 in the 2DS (B2DS) compared to the RTS. This suggests significant capacity reductions and asset stranding, where facilities are withdrawn before the end of their productive lives. In a recent analysis on coal, Carbon Tracker estimate global asset stranding risk associated with a below 2°C scenario of around $267 billion over the period to 2040 *(Carbon Tracker Initiative, 2018)*. The report further estimates that new renewable capacity will be 96% cheaper than operating existing coal capacity by 2030.

Remaining coal use is expected to shift away from power generation and towards industry. Under the 2DS, industry share of coal demand rises by 15pp to 2030, reducing demand for steam coal (lignite) while maintaining demand for coking coal. In the long term, coal continues to be an important input into many industrial sectors, including steel production, where coal is used to produce coke, the reducing agent used to convert iron ore into pig iron. Even in the B2DS, the iron and steel sector continue to consume 11 EJ of coal in 2060, around half of total industry final energy consumption.

Geographical differences in coal use are expected to be significant across the 2°C compliant scenarios, with coal shifting further toward non-OECD countries. Coal use in industry is expected to decline by around 35% by 2030 in the (B)2DS in OECD countries but only around 5% in non-OECD countries. Overall, non-OECD countries' share of global coal demand is expected to rise by 9pp by 2030. In power generation, while most countries are expected to completely phase out coal generation by 2050 under the below 2°C scenario, China and the US form notable exceptions with coal generation expected to continue past 2060, albeit on a downward trajectory.

Continued development in the coal sector is contingent on deployment of large-scale CCS. Commonly used scenarios assume significant uptake of CCS in the medium to long term. In the 2DS, captured CO_2 is projected to rise to 1.2 Gt in 2030 and 6.6 Gt in 2060. This level of deployment, according to Carbon Tracker analysis, would involve building one CCS plant capturing 1MtCO_2 every other day. The more ambitious B2DS scenario, which projects 10.9 Gt of annual CO_2 captured in 2060, would involve building more than five such facilities every week starting today *(Grant, 2018)*. For reference, Shell's Paris compliant Sky scenario would reach 8.4 Gt CO_2 captured annually by 2060 and would involve building some 10,000 large carbon capture and storage facilities over the period to 2070 *(Shell, 2018)*. The higher the uptake of CCS, the longer the use of coal can continue and the lower the value at risk from asset stranding.

At the same time, the range of CCS deployment estimates of these scenarios illustrate the uncertainty associated with the still relatively nascent technology: there are only 18 large-scale CCS facilities currently in operation worldwide *(Global CCS Institute, 2018)*.

Existing coal generation infrastructure could shift inputs towards biomass or gas, necessitating new supplier relationships. Coal generation facilities can be converted to use biomass as feedstock, as demonstrated by Europe's biggest biomass-fuelled power station, Drax power station in North Yorkshire, at which four out of six generating units at the facility can produce renewable electricity using biomass *(Drax, 2018)*. While gas could also act as an alternative feedstock, this report focuses on biomass as a lower carbon alternative and explores CCS as a separate option (which could also apply to gas generation facilities).

However, shifting inputs to biomass significantly affects generators' supply chain dynamics. While European coal imports of solid fuels (mostly coal) commonly originate from Russia, Colombia and Australia, *(Eurostat, 2018)* typical biomass supply chains originate in the US. At the same time, the handling requirements of coal and biomass in transport and storage differ significantly, for example, biomass is highly susceptible to water and damp, and becomes unusable if wet. As a result, transport vessels as well as generation plants need to be retrofitted to ensure these new risks are addressed sufficiently. Going further up the supply chain, US biomass supply chains are highly fragmented and can cause operational disruptions for generators due to seasonal fluctuations, handling problems and feedstock quality variability *(Sharma et al., 2018)*.

Litigation against large energy conglomerates for the physical damages caused by climate change, as well as regulation and permits, has already been observed but not yet been successful. To date, 14 US cities, counties and one state have sued fossil fuel companies for physical damages. For example, in 2008, the city of Kivalina, Alaska sued 24 oil, gas, coal, and utility companies claiming the destruction of the coastal city was a public nuisance caused by activities of the energy industry contributing to global warming. As with other notable cases of climate litigation against physical damages, such as *Comer v. Murphy Oil* and *American Electric Power Co. v. Connecticut*, the claim was unsuccessful. The difficulty for such climate change litigations is not only the difficult to establish causal links to physical damages, but also, in the US, the displacement of the federal common law by the Clean Air Act in the US such that the claims become non-justiciable. Although these legal precedents have set a high bar for future litigations, the risk of litigation costs and reputational impacts have prompted coal companies to clarify their positions on climate change and mitigate their impact.

Further legal action is expected to focus on intercepting the construction of new coal projects. These cases have been filed both against companies themselves as well as against local or national governments' regulation and permits. In an example of the former, *ClientEarth v Enea*, ClientEarth legally challenged a shareholder in Polish utility Enea, on the grounds that the planned 1GW plant would expose the company to 'indefensible' financial risk from carbon pricing and other developments. The case remains unresolved. A recent successful example is *Gloucester Resources Limited v Minister for Planning* in Australia, which refused the construction of a new open-cut coal mine in New South Wales for reasons including the mine's contribution to climate change *(Shannon, Wit and Seneviratne, 2019)*.

Additional cases against coal companies could focus on regulation and permits and disclosure of biomass lifecycle emissions. Commissioning of new coal mining or generation infrastructure could result in litigation aiming to withhold permits and uphold climate change regulation, even if national ambition as expressed in the NDCs is not compliant with the Paris Agreement. Where coal generators switch to biomass, they could face cases related to the lifecycle emissions of biomass in the future. This is an evolving area where reporting across all three scopes of emissions is not yet widespread. For example, in Europe, electricity from biomass needs to be proven to emit at least 35% less greenhouse gases than fossil fuels over their lifecycle, with new installations facing more stringent reduction requirements *(European Commission, 2019)*. However, this methodology does not account for changes in carbon stock of a forest or indirect impacts on carbon stocks of other land. As a result, should conventions change in the future, lawsuits could be filed against individual companies for underreporting environmental impact.

Implications for insurers

The transition of the sector on a 2°C pathway will present opportunities for the insurance sector, as outlined in *Table 1* below.

However, an overarching challenge relates to reputational risk for insurers, highlighted by the recent trend in the industry to limit exposure to coal. As of 2018, the total market share of non-life insurers that have limited support for coal was 7%, with Europe's four biggest primary insurers having all limited insurance cover for coal. Among reinsurers, some have limited coal cover, increasing the share of non-life reinsurers with restricted coal support to 33% as of 2017. Several pressures underpin these developments, including investor pressure, public opinion, political pressure, regulatory warnings and the growing climate risk for the insurance industry *(Bosshard, 2018)*.

Table 1: Opportunities and challenges for insurers in the coal sector

Trend	Opportunities and challenges	Affected classes of business
CCS	There is significant potential for new insurance contracts related to the scoping and construction of CCS projects given the expected uptake of CCS in scenarios such as the IEA's (B)2DS and Shell Sky. Once operational, labour costs constitute a significant component of overall costs of CCS plants in both the power generation and industry sectors *(Irlam, 2017)* and may increase demand for insurance. However, the lack of claims history and the low number of CCS projects currently in operation make it difficult to spread risk in these areas. In the longer term, especially given expected increases in carbon prices, costs of leaks could be substantial and limit insurer capacity to provide risk management solutions, necessitating government intervention.	Construction insurance for new CCS plants as well as technology risk insurance for scoping studies could represent first opportunities for interaction between insurance and CCS projects, as they are associated with shorter term risks that may be more easily understood as more projects become operational. D&O, professional indemnity and public liability insurance may all be in high demand given the uncertainty surrounding long-term liability for storage sites and accidents, but may be difficult to provide due to uncertainty over future carbon valuation and responsibilities. Employee insurance could play an important part of risk management of CCS plants and may not require significant updating of existing product offerings for insurers.
Biomass	Biomass supply chain risks represent project financing barriers that insurers can help address, though the quantification of these risks is a challenge. Sector interviews highlighted supply chain risk as a key barrier to project finance in both the biofuel and biomass generation sectors. Insurers could play a role in ensuring projects receive financing both by absorbing some risk and by helping clients to allocate risks along the supply chain efficiently. To play this role, insurers will develop a sophisticated understanding of the risks associated with biomass supply chains, which include uncertain lifecycle emissions and impacts on food production and can vary significantly by feedstock. The biofuel case study provides further detail on these risks and initiatives aimed at increasing transparency for financers and insurers.	Financial loss insurance, such as against business interruption or contract frustration are already in demand but difficult to price due to supply chain risk uncertainties.
Litigation	There is scope for additional liability insurance for remaining coal producers and generators given likely increase in litigation focusing on physical damages and regulation and permits. While a potential opportunity in the future, industry engagement did not identify this as a priority area for coal users and producers, as there have yet to be credible precedents of successful cases.	The coal sector may increasingly wish to purchase D&O, professional indemnity and public liability insurance to address risks arising from climate change litigation, however, the continued insurance of coal companies may present challenges for insurers, as does the uncertain future of these types of cases and their success rates.

Marine

Marine

The low carbon transition affects marine transport directly through emissions reductions and indirectly through changes in trade patterns.

– Opportunities relate to the adoption of low emissions technologies, with premium income expected to grow as insurable values of vessels increase and the set of insured risks, including risks on compliance with new regulations, broadens. There is a potential role for insurers in facilitating this investment by supporting more effective risk sharing between vessel owners and charterers.
– Challenges relate to the uncertainty around the future mix of regulations and technologies, which may involve biofuel or hydrogen, as well as an expected decline in the fossil fuel subsector.

Transition impact on sector

The impacts of a low carbon transition on the marine sector can be disaggregated into direct and indirect impacts. Direct impacts describe those from the need for decarbonisation of marine transport, while indirect impacts refer to the effects of other sectors' decarbonisation on the marine sector, propagated through trade patterns.

Direct impacts: to contribute to global action on climate change, the IMO in April 2018 set a global ambition to reduce total annual GHG emissions from shipping by a minimum of 50% by 2050 compared to 2008. While shipping accounts for 2-3% of global GHG emissions today, the IMO forecasts that this share will grow by between 50 and 250% by 2050 under a business as usual scenario *(Smith et al., 2015)*. Shipping and aviation are not directly included in the Paris Agreement, but the challenge lies instead with the International Civil Aviation Organisation (ICAO) and the IMO to reduce global emissions from their respective sectors *(UNFCCC, 2016)*.

Energy efficiency measures and slow steaming can contribute to the sector's decarbonisation but will not be enough to meet long term targets. Technical measures to increase the energy efficiency of a ship include, for example, the use of lighter materials and propulsion improvement devices such as wind turbines, sails, flettner rotors and kites. However, to reduce shipping's total emissions while meeting increasing transport demand, shipping will need to reduce its carbon intensity by more than energy efficiency measures alone can achieve. Operational measures, such as reducing speeds, ship size and optimising ship-port interfaces, could also reduce emissions. However, results from modelling of a range of regulation, demand and technological development scenarios, suggest the employment of low novel carbon technologies will be required over the longer term *(Smith et al., 2016)*.

Zero emissions vessels need to become operational by 2030 according to the IMO's ambition, but it is not yet clear which technology most of these vessels will employ. While the marine shipping industry is exploring a variety of technology options, these are still relatively novel and have never been deployed at scale. A recent study by the Lloyd's Register identifies biofuels as the most profitable zero-emissions solution, followed by ammonia and hydrogen with internal combustion machinery *(Lloyd's Register and UMAS, 2017)*. Due to their relatively low capital cost in implementation, fuel and voyage costs, biofuels currently represent the most attractive option to industry. However, biofuels face two key challenges in implementation. First, biofuels need to be *sustainable* in the sense that they should not compete with other basic needs of society such as food supply. Second, biofuels need to be *available* at the scale required to become the majority fuel of the shipping industry, which, depending on feedstock, could result in significant amounts of land diverted from alternative purposes. As a result, it might still be necessary to employ a mix of abatement technologies in the shipping sector. A range of risks will emerge as the industry adapts: machinery is prone to damages from new fuel types; new storage and refuelling facilities are required at ports; and biofuel refineries need to scale up to meet marine transport demand.

Regulation can require companies to explore decarbonisation options and begin to implement them to this timeline, but there is considerable uncertainty surrounding future IMO regulation. While the IMO's 2020 sulphur cap regulation is a useful case study of how future international GHG emissions regulation could be implemented, it also demonstrates that this could be complex and costly.

Twelve years separate the agreement on draft regulation of the sulphur restrictions from them coming into effect, highlighting the complexity of negotiations with the IMO's 174 member nations. Even if carbon regulation is implemented, compliance could present a separate issue: if countries do not ratify IMO regulation into national legislation, the capacity of ports to enable decarbonisation options could be limited.

Indirect impacts: the marine shipping sector is likely to experience indirect impacts of the low carbon transition through shifts in goods transported. Growth in other sectors is critical to marine transport, as 80% of global trade is carried by sea and a third of maritime trade currently comprises fossil fuels. The economy's move towards alternative energy sources, such as biomass, could change the relative importance of cargo transported. The quantity of wood pellets exported by the US increased by 78% between 2013 and 2017 fuelled by climate regulation-induced demand from Europe *(Ireland, 2018)*. Similar growth could occur in other low carbon sectors such as renewables equipment and lithium. If these sectors outpace growth (and eventual decline) in fossil fuels and industry, the relative importance of different types of cargo is likely to change, and with it, the risk profile of global marine trade.

For example, biomass is highly combustible and needs to be protected from damp, while lithium ion batteries are classified as dangerous goods and must follow relevant regulations.

Changes in cargo could be accompanied by changes in routes travelled. Source and destination countries of low carbon alternatives will likely differ from those of fossil fuels. As an example, US-Europe routes could become more travelled as the share of wood pellets and other biomass in global trade increases. Different routes imply different risks for marine transport companies and their insurers.

Litigation: Climate-related litigation risk in the sector is likely to arise from climate-related disclosure and IP risk associated with new technologies:

Corporate climate commitments could prompt future climate-related disclosure litigation. To list a few examples of these commitments, APM Maersk, the world's largest container shipping company, has announced its ambition to reach net zero operational emissions by 2050 and Evergreen have announced its ambition to reduce CO_2 emissions by 70% over the same time period (relative to 2008). Though these ambitions are non-binding, a failure to fulfil them may nonetheless result in future shareholder legal action against the company. At the same time, a failure by companies to disclose key business risks from alternative fuels and emissions reductions or to set clear targets could also lead to disclosure litigation over withholding information vital to the business.

New technologies may carry significant IP risk for marine shipping companies, which could lead to further demand for litigation insurance. Ship owners and charterers performing in-house research into abatement options are often hoping to gain a competitive advantage from the early implementation of such technologies. As a result, they are likely to become increasingly concerned about securing this advantage through intellectual property rights.

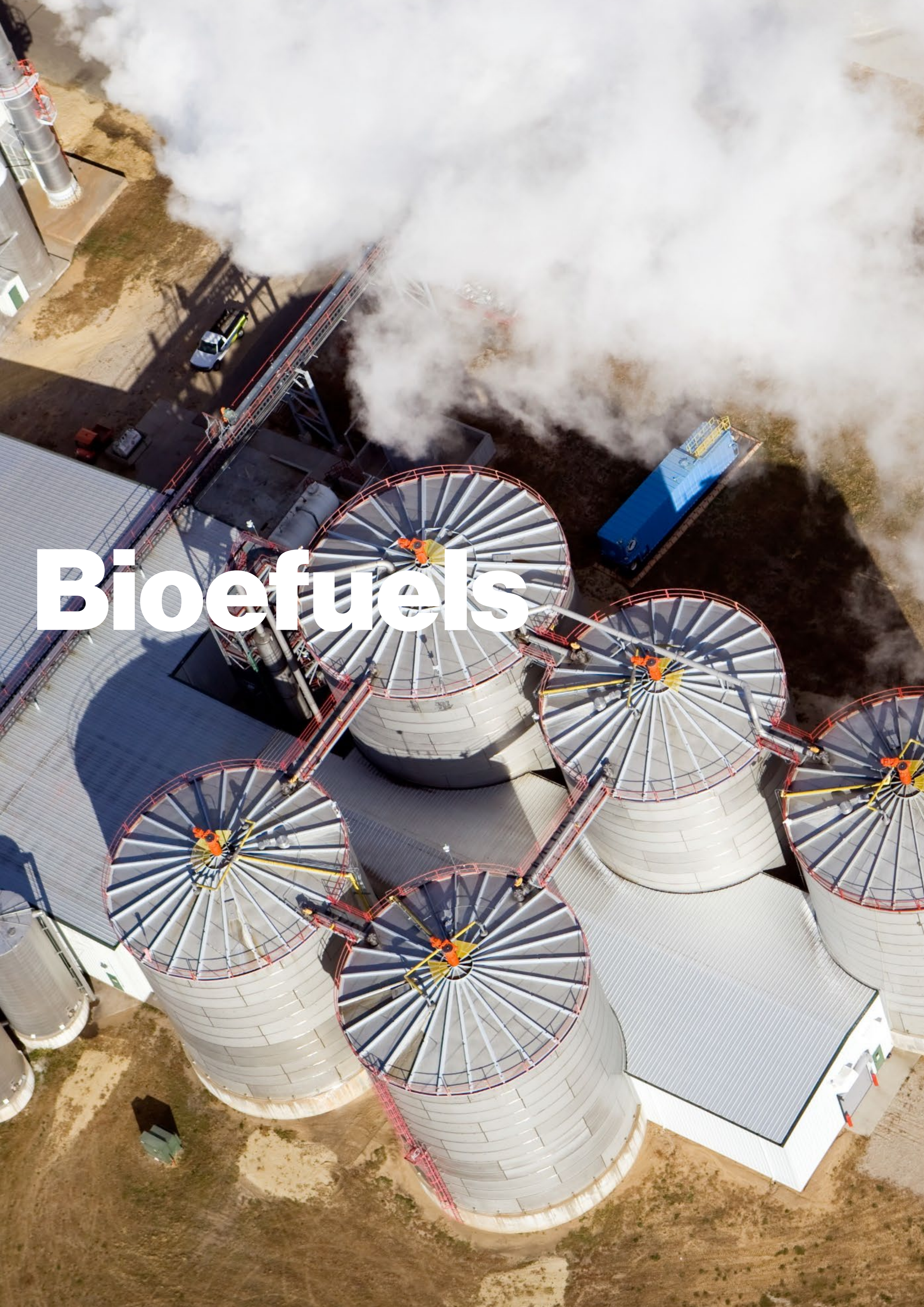
Implications for insurers

Both the direct and indirect impacts of the low carbon transition on the marine shipping sector could have significant implications for insurers. Opportunities and challenges associated with key sectoral trends are detailed in *Table 2*. While some segments such as cargo insurance are likely to decline others, such as liability insurance, are expected to grow.

Table 2: Opportunities and challenges for insurers in the marine transport sector

Trend	Opportunities and challenges	Affected classes of business
Decarbonisation technologies	Shipowners and charterers both see a need to collaborate on the research and implementation of new technologies, but would like to share risk more effectively. This could provide opportunities for new contracts that facilitate risk sharing and transfer. Insurable values of vessels are set to rise from implementation of retrofits and the implementation of costly new technologies, possibly increasing hull insurance premiums. Long-term technologies offer a range of opportunities for insurance provision, such as biofuel storage and transport risks around bio growth, wind turbine corrosion and explosion risk of hydrogen technology. However, uncertainty associated with the deployment of different technologies and associated upstream emissions could make risks difficult to price.	Technology risk insurance for shipowners and charterers exploring new decarbonisation options for their vessels and may also interact with charterer's insurance. Changing risk profiles may impact hull insurance premiums or insurance of vessels under construction, for example, if biofuel has different risks in use at sea than fossil fuels related to spills and bio-growth, or if the installation of wind propulsion technologies carries particular risks.
Changes in cargo and routes	Growth in transport of biomass could increase ship owner and charterer exposure to off-gassing incidents, combustion and other risks, potentially affecting cargo insurance demand and chargeable premiums. Changing routes, for example, with a higher share of trade between the US and Europe and a reduction in traffic in certain straits, could impact aggregate levels of accident risk and related insurance product demand and pricing.	Cargo insurance of fossil fuels is likely to shrink over time, as demand for the products falls. At the same time, cargo insurance of low carbon cargo is set to grow over time and necessitates insurers increasing capabilities to measure associated risks. Route changes may affect all marine classes of business if relevant risks are affected, such as kidnap and ransom, ship's crew personal accident cover and political risk.
Regulatory changes	Future IMO regulation could create compliance obligations for port and ship owners and operators. Depending on the timeline and ambition of future IMO regulation on GHG emissions, this could lead to early scrappage and expensive retrofits affecting profitability in the sector and reducing insurance demand.	Political risk insurance could help ship owners and charterers address risks associated with non-compliance with IMO regulation in certain regions. Insurance demand and capacity may be affected if the sector's profitability suffers from future carbon regulation.
Litigation	Trends towards climate-related disclosure and target setting in the marine sector could result in future disclosure regulation for which companies may be interested in purchasing liability insurance. Demand for intellectual property insurance products could rise as more companies research effective abatement technologies to gain competitive advantage.	D&O insurance against directors and officers setting climate-related targets. IP insurance for companies undertaking significant efforts on low carbon innovation.

Biofuels



Biofuels

The biofuels sectors could experience large increases in demand, but technologies have not yet proven to be deployable at scale.

Insurance could aid new projects attract financing, but uncertainty surrounding key risks presents challenges. Demand for biofuel is expected to increase significantly over the period to 2050, accompanied by a shift from road transport to aviation and marine as the key customer bases, which will require new feedstocks that are able to address the sustainability concerns of today's feedstocks, including lifecycle emissions, alternative uses of the land and water use. For insurers:

- Opportunities relate to supporting the sector's growth, including through insurance over technological, regulatory, supply chain and litigation risks.
- The key challenge is uncertainty, with a lack of quantitative information on the diverse and context-varying risks faced by operators in the sector.

Transition impact on sector

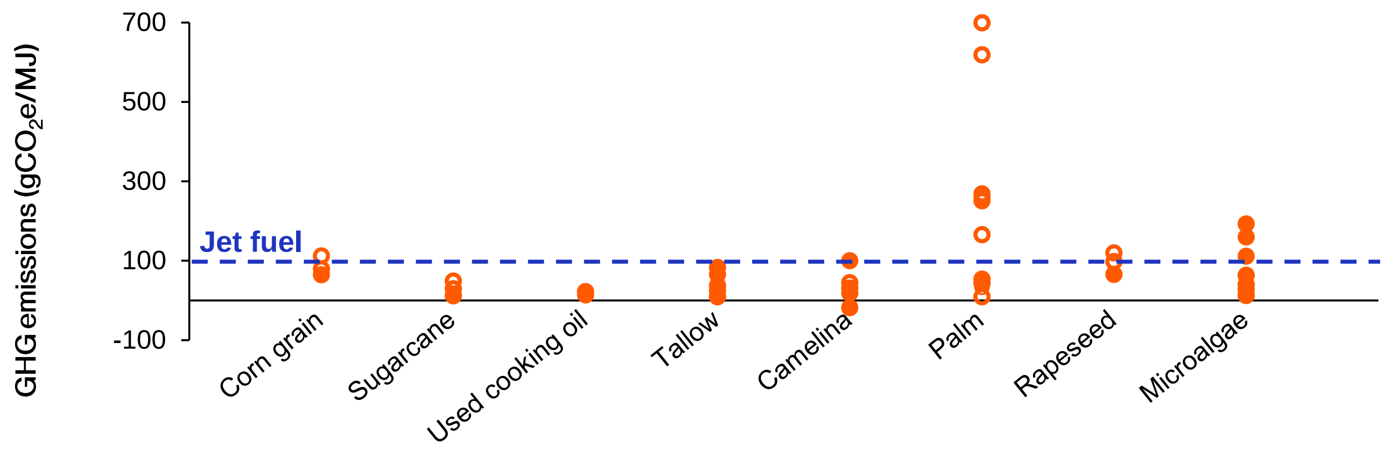
Under decarbonisation pathways, biofuels meet 10% of global transport fuel demand by 2030 compared to 3% today, but production is not yet increasing quickly enough to meet this demand. Despite 7% year-on-year output growth in 2018, the IEA anticipates only 3% average annual production growth over the next five years – significantly below the 10% growth rate required to meet 2030 targets *(Feuvre, 2019)*. Geographically, biofuel use is concentrated in a few large markets, with 90% of transport use of biofuel in Brazil, China, the EU and the US. While China and the ASEAN region are exhibiting growth rates consistent with the estimated global increase in demand during a low carbon transition, the US, EU and India are projected to lag behind annual production growth required under the scenario *(OECD/IEA, 2017)*. Supply chain risk has contributed significantly to the slow development of bio-projects through its impact on debt costs. Rapid growth in bioenergy production requires a supply of capital at low cost. However, the risks associated with biomass supply chains are currently not well understood, with no established protocols, standards or recognised industry best-practices to rely on to empirically quantify these risks. This has resulted in most bioenergy projects carrying a BB rating or less – 'junk' ratings. In the US, the Department of Energy is developing potential Biomass Supply Chain Risk Standards (BSCRS) to cover more than 90% of recognised risk factors. The explicit aim of this development is to provide a solution to the problems of high debt costs and slow bio-energy project development through increasing transparency *(Nair and Emerson, 2019)*.

Biofuel could become the majority fuel of both aviation and marine transport by 2060 in the 2DS, shifting from conventional use in road transport. Correspondingly, the net-zero toolkit estimates an increase in profit under the 2DS (B2DS) relative to the RTS of 32% (40%) by 2050. To 2030, progress is expected to be modest, with 10% of aviation fuel demand and 5% of shipping met by biofuels. While progress has been made in aviation, with flights using biofuel blends exceeding 150,000 and continuous biofuel supply available at five airports globally, biofuels accounted for less than 0.01% of aviation fuel demand in 2018 *(Feuvre, 2019)*. The marine sector is considering the use of biofuels but has not yet employed them at a noteworthy scale. The lack of a supportive global or regional regulatory environment for biofuels in aviation and marine represents a significant barrier to adoption.

The shift in customer base is likely to be accompanied by a shift in dominant feedstocks from conventional biofuels to advanced biofuels that can address key sustainability concerns. Advanced biofuels are sustainable fuels sourced from non-food crop feedstocks, capable of delivering significant lifecycle emissions reductions compared with fossil fuel alternatives. They do not directly compete with food and feed crops for agricultural land or cause other adverse impacts on sustainability. These could include cellulosic materials, fibrous parts of plants such as grasses, wood or algae that are inedible to humans and animals, which can be grown on non-arable land or are produced as waste during food or feed production. These fuels could replace conventional biofuels such as bioethanol or certain types of biodiesel, which are unlikely to be suitable for application in aviation and shipping.

Yet even the same feedstock can exhibit a wide range of GHG emissions per unit of energy delivered, in some cases exceeding those of conventional fossil fuels. *Figure 1* below illustrates the variation of GHG emissions per megajoule across feedstocks and estimates *(Takriti, Pavlenko and Searle, 2017)*. The analysis, which covered a wide range of feedstocks for alternative jet fuel production (the figure below contains only a subset of these to illustrate the ranges of emissions across estimates), highlights that fuels produced from sugar and starch feedstocks deliver only small emissions reductions compared to conventional jet fuel, whereas those made with vegetable oil based feedstocks tend to exceed conventional carbon when land use change effects are taken into consideration. The only alternatives shown to consistently provide substantially lower emissions are lignocellulosic and waste feedstocks.

Figure1: Carbon intensities of selected alternative jet fuels



Note: Unfilled dots incorporate estimates of land use change emissions.
Source: Adapted from Takriti, Pavlenko and Searle, 2017

Lifecycle emissions could become the focus of future litigation against biofuel producers and users. Even where biomass lifecycle emissions are covered by regulation, these could become subject of significant future litigation if new measurement methodologies are developed in the future. The EU's Renewable Energy Directive details the sustainability criteria for biofuels and bioliquids, including, for example, when land can be converted for use of biofuels if it is currently a carbon stock, and the minimum GHG reduction biofuels must achieve relative to fossil fuels over their lifecycle. However, even if such regulation is in place, quality assurance and control remain challenging for the sector, meaning compliance could become a target of future litigation. At the same time, assessments of lifecycle emissions and other sustainability impacts are expected to become more sophisticated in the future and could lead to litigation even where regulation had previously been complied with under old accounting standards.

Other areas of litigation may concern intellectual property of new technologies, particularly given corporate research projects into establishing company-specific value chains. In May 2019, United Airlines agreed to purchase up to 10 million gallons of sustainable aviation biofuel from Boston-based biofuel supplier World Energy. The biofuel is used on all flights departing out of the Los Angeles Airport hub (LAX). United Airlines biofuel supply agreements represent more than 50% of the aviation industry's sustainable aviation biofuel agreements *(United Airlines, 2019)*.

Due to the uncertainties associated with new biofuel feedstocks, it is likely that those investing in and carrying out relevant research will have concerns related to securing intellectual property. Legal action may be seen as necessary to protect competitive advantages gained from being early movers on particular technologies.

'Waste-to-energy', which encompasses energy generation from municipal or food waste and sewage, is considered a distinct, albeit adjacent, sector to biofuels. While it is relatively well established in European markets, there is significant technical innovation in the sector and take-up is growing in North America, largely driven by regulation. The technological and regulatory issues discussed below for biofuels, therefore apply in a parallel fashion to this sector.

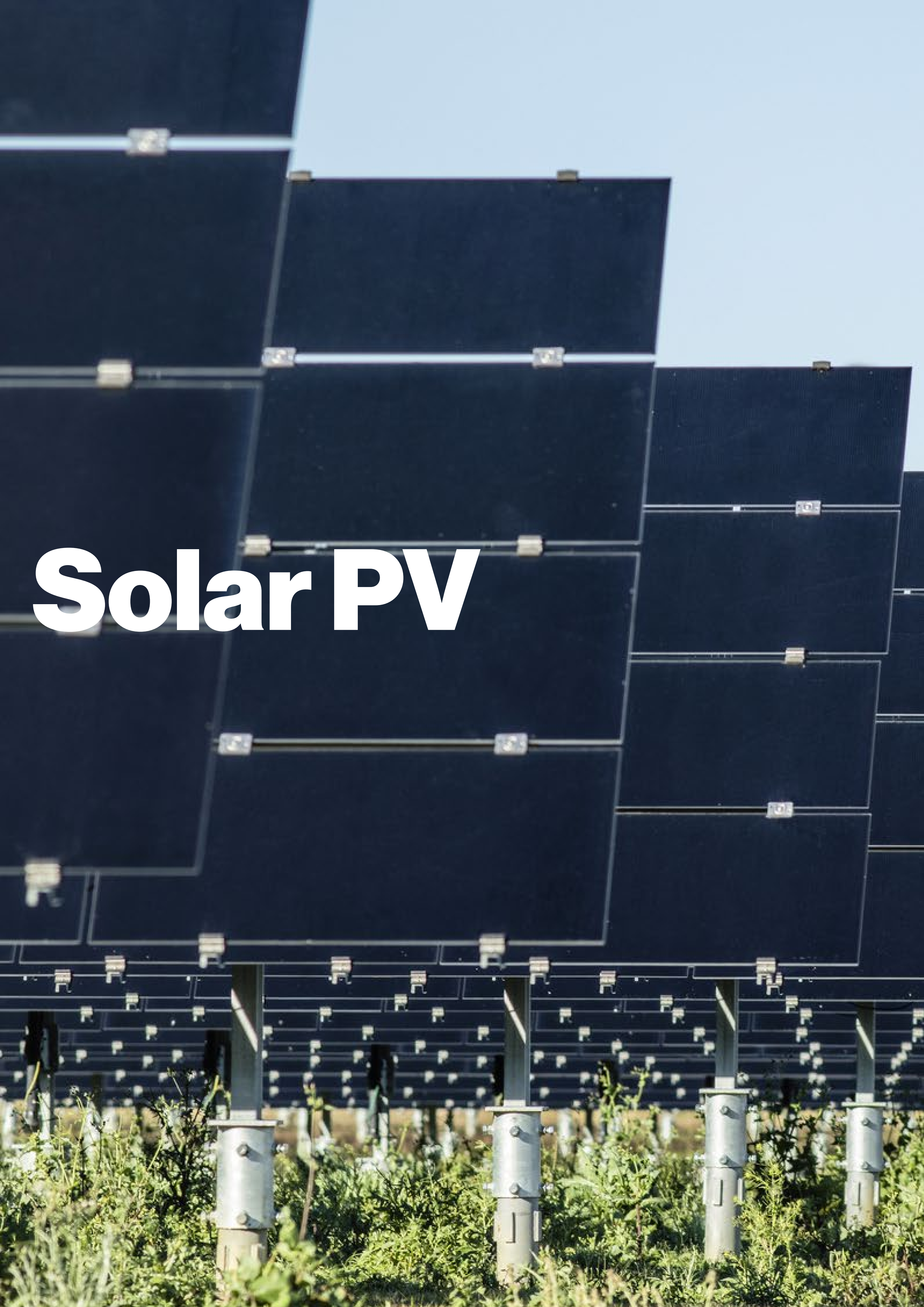
Implications for insurers

The biofuel sector is set to undergo significant transformation, presenting insurers with opportunities to support the sector in addressing key risks while managing challenges around risk quantification. The level of insurance demand from the biofuel sector is likely to be very significantly higher under a 2°C pathway than under the reference scenario – and insurers can play a broader role in helping the sector to reach this scale. The key opportunities and challenges associated with sectoral trends are detailed in *Table 3*.

Table 3: Opportunities and challenges for insurers in the biofuel sector

Trend	Opportunities and challenges	Affected classes of business
Technology risk	The myriad risks associated with new technologies, including their research, could provide many opportunities for innovative insurance products Uncertainty over risks associated with biofuel production, varying widely by feedstock, with no single easy-to-source feedstock having yet been identified. As a result, the costs to insurers of determining appropriate risk premia of related products could be significant.	Technology risk associated, for example, with exploring the market potential of different feedstocks and waste to energy.
Supply chain risks	Insurance of supply chain risks over quality and volume of feedstock could alleviate high barriers to financing for biofuel producers. The forthcoming publication of US biomass supply chain risks standards (BSCRS) is likely to be a first step toward increased insurer understanding of key risks involved in biofuel production.	Financial loss insurance, such as against business interruption or contract frustration are already in demand but difficult to price due to supply chain risk uncertainties.
Regulatory risk	Regulation insurance products could reduce uncertainty regarding future pricing environments on low carbon fuels for different transport modes.	Regulatory risk insurance could help biofuel producers address risks associated with shifts in government support for different uses of biofuels.
Litigation risk	Unsustainable bioenergy could have significant repercussions for food security, water scarcity and land quality, implying liability risks that are difficult to understand.	D&O, professional indemnity and public liability insurance where lifecycle emissions were incorrectly reported or measured, especially given quality variation. IP insurance for companies undertaking significant efforts on low carbon innovation.

Solar PV



Solar PV

The rapidly growing solar PV sector presents a host of significant opportunities for insurers.

- Opportunities relate to the sector's rapid expansion and evolution. In particular, insurers can support new contractual relationships that will emerge as subsidies decline, the sector expands in emerging markets, and 'prosumer' and corporate power purchasing agreements (PPAs) become more prominent. This can encompass regulatory risks pertaining to contracts with grids or public sector offtakers.
- Rapid growth and innovation also brings risks, most notably in maintaining project risk management standards as inexperienced supply chains are engaged and in understanding risks associated with novel contracting relationships. The growth of domestic rooftop installations is a challenge as it may also affect other property risks – for example if they inhibit firefighters.

Transition impact on sector

Globally, the installed capacity for solar PV is set to grow at about 10-20% per year in the next decade. Installed capacity of PV has grown from just 15 GW in 2008 up to over 500 GW by the end of 2018 *(IRENA, 2018)*. This was driven largely by the reduction in the costs of solar energy and the introduction of supportive policies in many countries. The levelised costs of electricity from unsubsidised utility-scale solar projects have fallen by 88% in the nine years between 2009 and 2018 *(Lazard, 2018)*. These same drivers will sustain the growth of solar PV in the next decade.

> *Under the 2°C compliant scenario, solar PV capacity reaches 1150 GW in 2030, with forecasts suggesting average annual growth rates of between 15-25% between 2019 and 2023* (Solar Power Europe, 2019).

Emerging markets and rooftop installations are increasing their share of solar PV deployment. In terms of geography, China will remain by far the largest market for the medium term, both in installed capacity and annual additions. However, there is a gradual shift towards other emerging markets. The Chinese market is projected to grow at around 21% per year up to 2023, which will be significantly slower than India and Pakistan (35%), Mexico and Brazil (40%), and Saudi Arabia, the UAE and Egypt (50%+). In terms of installation type, utility-scale PV is currently more widespread than rooftop solar. Installing utility-scale solar has been easier than establishing a distributed PV rooftop market, which takes substantial time and effort to educate consumers and create suitable technical standards. However, the share of rooftop solar is projected to rise due to several reasons. Technological improvements in battery storage and digital energy management systems enable households and companies to deploy rooftop solar in an economical way. The growing use of electric vehicles and other smart city technologies also have synergies with rooftop solar. Active policy support, including subsidies for renewables and favourable market designs, are encouraging more rooftop solar installations.

The shift to rooftop solar within the EU is particularly boosted by policy changes. At the time of writing, the ongoing legislation for the Clean Energy Package includes the following features *(Solar Power Europe, 2019)*:

- Exemption from charges/fees for self-consumed electricity up to 30kW with cost-reflective charges and market value remuneration for electricity fed into the grid;
- Simpler administrative procedures to enable the growth of small-scale plants;
- Shorter permitting deadlines up to one-year for installations below 150kW and simple notification for small solar projects equal or less than 10.8kW;
- Technology specific tenders and feed in tariffs (FiTs) for small scale installations, with the possibility of exempting small scale installations and demonstration projects from tendering procedures;

– Priority dispatch is maintained for small renewable installations up to 400kW (200kW from 2026).

Europe is further leading the way on regulation for PV solar panels and waste control after they are decommissioned with regulations including PV-specific collection, recovery and recycling targets. The EU Waste of Electrical and Electronic Equipment (WEEE) Directive entails all producers supplying PV panels to the EU market to finance the costs of collecting and recycling EOL PV panels in Europe (Chowdhury et al, 2020). No other regulation has been laid out worldwide and it is likely that the EU's regulation will guide other countries regulation with manufacturers carrying much of the risks once PV panels are decommissioned.

Changes in policy environments and technologies are enabling new business models, such as self-consumption ('prosumers') and direct bilateral power purchase agreements (PPAs). Traditionally, incentives to solar PV project developers have been driven by FiTs or other forms of subsidies, embedded in state-guaranteed PPAs with authorities, utilities or grid operators. In Europe, this remains as the most widespread re-financing scheme for solar installations. However, FiTs have been cut back in many countries in recent years because the costs of solar energy have fallen sufficiently to remove subsidies. This is in part the reason for the emergence of new business models:

– Prosumers. Prosumers in this context refers to households or businesses that both produce and consume electricity on their own. Under this model, the prosumer typically invests in rooftop solar panels to supply power to itself and enters into a contract with a grid operator to sell off excess electricity when its power demand falls below that of the power supply from the installation. This trend is closely linked with policy and technology developments mentioned earlier that encourages the deployment of rooftop. The incentive to become a prosumer is greater when the costs of solar-generated electricity are much lower than retail electricity prices.
– Merchant solar. Rather than selling electricity to wholesale markets, more solar project developers are entering bilateral PPAs with utilities or large power consumers. This will be seen primarily in countries where there are the widest spreads between solar prices and wholesale power prices, and where access to ancillary services is granted. The long-term nature of PPAs provide predictability over future cashflows for a solar project, thereby making it desirable to lenders and investors. In the absence of government support such as FiTs, these PPAs help project developers secure finance. One of the fastest growing business models is the use of corporate PPAs (cPPAs). The popularity of cPPAs is driven by the strong demand from corporates seeking to procure renewable energy. In 2018, a record 13.4 GW worth of cPPAs deals were signed, more than doubling that of 2017 *(Solar Power Europe, 2019)*. Technology companies like Google and Amazon are forerunners of this model. These PPAs can differ in many ways, such as whether there is physical link between the solar installation and the customer, whether the price is fixed, and whether the volume procured is fixed. These terms determine the allocation of risks between the buyer, seller and (potentially) intermediaries. In recent years, many different PPAs have been developed to improve risk-sharing.

The solar panels manufacturing sector is experiencing high rates of consolidation, with some concerns over IP theft. Photovoltaic technology has matured in recent years and cost reductions are driven mainly by improvements in manufacturing process. Price decline is set to accelerate market consolidation across the supply chain, particularly hitting PV module makers and cell manufacturers. Furthermore, multicrystalline silicon panels which currently dominate the market are gradually displaced by cheaper monocrystalline silicon panels, and by Mono-PERC in the longer term. Depending on the pace of this development, the adoption of newer products could render old manufacturing facilities obsolete. This impact is strongest in China, where most solar panels are being made and there are several cases of bankruptcies in recent years, such as the case of Suntech Power. Furthermore, there has been a high-profile case of IP theft where SolarWorld alleged that Chinese hackers have stolen technologies required to make PERC solar modules and turned it over to a Chinese competitor. However, it is unclear whether this will remain a one-off incident or part of a broader trend as the value of PV technologies increases.

Implications for insurers

Demand for solar energy insurance will expand rapidly as the solar PV capacity grows. With global solar PV capacity at least doubling in the next 10 years, global demand for solar energy insurance is set to rise at a similar pace. Existing forms of solar energy insurance vary depending on the type of installations. Residential rooftop solar have been embedded into some home insurance policies. By contrast, commercial and utility scale solar projects tend to be covered by comprehensive policies introduced by specialist underwriters, spanning the entire project development and operational cycle. However, many solar project developers and their offtakers remain exposed to certain types of risks as discussed below. This is because most existing solar energy insurance focuses narrowly on technical and operational perils. There is an active discussion on how contractual structures, derivatives or insurance instruments can improve risk allocation.

The evolving nature of business models and risk management in the sector presents both risks and opportunities for insurers shown in *Table 4* below.

Table 4: Opportunities and challenges for insurers in the solar PV sector

Trends	Opportunities and challenges	Responses by insurers
Credit risk of commercial & industrial (C&I) offtakers	Tax equity and debt lenders for solar projects generally require that the electricity offtaker has a public credit rating. Unlike utility offtakers, some C&I offtakers do not have a public credit rating or are below investment grade, preventing them from participating in C&I PPAs.	Insurance product that transfers the risk of offtaker default to an insurance company. It is similar to trade credit insurance, but additionally supplies an insurer's public credit rating.
Offtakers exit or renegotiate PPAs	A growing concern regarding offtaker risk is driven by falling solar energy prices, which incentivise offtakers to exit or renegotiate existing deals. This is particularly salient in Africa where price reductions are steeper.	No prominent examples, but there is a potential to cover such risks in trade credit insurance.
Developers' exposure to shape risks in virtual PPAs (vPPAs)	The intermittency of weather conditions creates uncertainty in the *volume* of power generation. Fluctuations in energy demand and supply create *price* risks. The interaction between weather intermittency and energy prices is known as *shape* risks – a surge in solar energy supply on a sunny day can depress prices. Fixed-volume swaps and virtual PPAs protect project developers from volume and price risks respectively, but not shape risks.	Proxy revenue swaps (PRS) to protect project developers against shape risks, in addition to volume and price risks *(Norton Rose Fulbright, 2018)*. Under a solar PRS, the hedge provider pays the developer a *fixed* lump-sum amount per quarter/year that is independent of weather conditions and the market-clearing price for electricity. In return, the developer pays the hedge provider a *floating* amount each quarter equal to the 'proxy revenue' – calculated using agreed formula that accounts for weather conditions. No energy is purchased as part of this transaction, leaving the developer free to sell energy into the local grid at market prices. In effect, the developer has swapped the uncertain annual volume of electricity that would be generated by an efficient project with a payment at a fixed long-term price. (2016).
Offtakers' exposure to volume risks in vPPAs	In vPPAs, C&I offtakers often face significant financial uncertainty. They have to settle with quantities of electricity that may not align with their actual demand. For instance, on a sunny day, the offtaker can end up purchasing too much electricity.	Proxy generation PPAs and volume firming agreements to transfer such volume risks away from C&I buyers *(John, 2019)*. A Proxy Generation is calculated as the expected amount of energy generated after accounting for weather conditions, power generation technology and expected operations. Conceptually, the C&I buyer receives a variable Proxy Generation amount of electricity that it swaps with the weather (re)insurer for a fixed amount of Proxy Generation electricity, protecting offtakers from weather-related risks.
Project risk manageme nt	The rapid development of the solar PV sector has come with deteriorating project standards for several reasons, such as operating in frontier markets where supply chains are less developed, increasing solar panel theft, and poorer quality of equipment and grid connection.	The substantial technical and operational risks make insurance for solar projects more expensive. The lack of operational data further prevents insurers from accurately pricing such risks.
Small scale rooftop solar	Owners of small scale rooftop solar have less appetite for production-related insurance as compared to utility-scale solar installations.	It is now popular for home insurance to include an optional coverage for solar panels. Potential to sell households and businesses affordable insurance against risks such as curtailment and grid connection issues.
Regulatory risks	The returns and feasibility of solar projects, regardless of the business model, depend significantly on legislation. These include frameworks around Guarantees of Origins, grid charges, and taxes on electricity. Solar project investors are acutely aware of such risks and have an appetite for appropriate insurance against them.	Providing insurance against regulatory risk is currently underexplored.
Litigation and liability risks	Risks associated with bankruptcies, M&A and IP thefts would become a concern for manufacturers.	This presents a growing demand for D&O and IP insurance.


Construction

Construction

Regulatory shifts will determine decarbonisation pathways in the construction sector, which are likely to increase the adoption of new materials and offsite construction techniques. Though the size of the sector will not be significantly affected by transition, changes in production methods, supply chains and regulatory obligations will have appreciable impacts on the insurance market.

- Opportunities stem from changes in production and regulatory risks that the Lloyd's marketplace's expertise is well positioned to serve. An accelerated shift towards offsite modular construction is expected to reduce attritional physical damages but increase large, low frequency losses, many of which will relate to liability claims. Increasingly onerous compliance and disclosure obligations are expected to increase demand for insurance against related liabilities.
- Risks relate to varying and in some cases unclear assignments of responsibilities between building manufacturers and contractors, as offsite methods become more widely adopted. As well as low carbon construction materials that might increase fire load and risk.

Transition impacts on sector

> *Globally, buildings and construction sectors combined are responsible for 36% of final energy consumption and close to 40% of CO_2 emissions* (IEA, 2019).

While efforts to decarbonise the construction sector in the last decade have prioritised reducing *operational carbon*, such as improving energy efficiency of heating and cooling, growing attention will be placed on reducing *embodied carbon*, which is driven by the lifetime carbon footprint of the materials used.

Although the low carbon transition does not have a significant impact on the overall size of the construction sector, demand for retrofits and green infrastructure projects will grow. The construction sector is relatively insulated from the incentive policies that are seen elsewhere in energy-intensive sectors. As a result, demand for construction does not experience any direct impact. Nonetheless, there is an indirect impact driven by the demand for energy efficiency retrofits in both industrial and residential buildings, as well as the surge of green infrastructure investments.

The adoption of low carbon building materials and construction methods will alter risk profiles and create new supplier relationships. In the past, the construction sector focused on improving energy efficiency in buildings via reducing operational carbon, such as heating, cooling and lighting. With a falling share of building emissions coming from operational carbon, there is growing attention on embodied carbon instead. This involves reducing the energy used to extract and process building materials, assemble and transport components, construction, maintenance, deconstruction and disposal. This translates into changes in two key aspects in the sector:

- Building materials. A variety of low carbon building materials is being adopted in recent years. These include natural materials (timber, straw, hemp), recycled and secondary aggregates (recycled concrete, metallurgical slags), and new alternative materials such as low/negative carbon cement. This allows a partial substitution away from the use of steel and cement, which require energy intensive extraction and processing.
- Construction processes. Offsite construction (also known as 'pre-fabrication' or 'modular construction') is another key trend in the construction sector. This is partly driven by build time and quality considerations, and partly driven by the aim to reduce waste material and energy. The global modular construction market is projected to grow at an annualised rate of 6.9% from $110 billion in 2018 to $160 billion by 2023 *(MarketsandMarkets, 2018)*.

These changes will be accelerated by tightening building standards and growing customer demands. In line with the growing focus on embodied carbon, there is increasing consensus that building regulations and certification schemes should include embodied carbon and life cycle assessments (LCA). There are already provisions on embodied carbon under BREEAM and LEED, two popular certification schemes. In the future, building regulations are expected to handle embodied carbon in the same way as energy efficiency ratings currently are, with highly standardised calculation methods and cost-efficient and robust processes. The first regulatory limits for LCA based material impacts are in force in the Netherlands. France and Nordic countries are developing new regulations to address embodied carbon. From the perspective of contractors, compliance with more stringent building standards and customer demands will be difficult due to the complicated supply chain for building materials.

Efforts are underway to establish repositories that hold data on embodied carbon, such as the WRAP Embodied Carbon Database based in the UK.

Implications for insurers

None of the trends in the construction sector are fundamentally disruptive and all occur at a gradual pace, but the effect of transition on construction will nonetheless lead to shifts in the level and allocation of risk in a way that will have an impact on insurance markets. The opportunities and challenges for insurers are outlined in *Table 5* below.

Table 5: Opportunities and challenges for insurers in the construction sector

Trends	Opportunities and challenges	Examples or potential responses by insurers
Offsite construction	As a greater share of construction processes occur offsite, risks are shifted to offsite manufacturing facilities. This generates greater insurance demand for offsite activities and transit processes. The fact that offsite construction takes place in safer, controlled environments means that 'attritional' risks of low-level physical damages are likely to be reduced. But on the other hand, when losses do occur they are likely to be larger in magnitude. In the absence of common design standards and significant claims histories, these risks are likely to be difficult to measure. Greater offsite construction is expected to lead to a transfer of liability risk over the building performance from contractors to manufacturers. If the allocation of this risk is unclear, it represents a challenge for insurers.	Insurance might reset the coverage and premium rates of insurance against physical damages in construction to match shifting risk profiles. For professional indemnity and building defects insurance, insurers may proactively require contractual terms between manufacturers and contractors that unambiguously and efficiently allocates liability risk.
Low carbon materials	While regulations will ensure only materials that meet a set of minimum performance standards are adopted, the long-term performance of new materials is uncertain. This creates financial uncertainty, such as the extent of maintenance and repair work required over the lifetime of buildings. Although the construction sector has been used to managing the performance risks of building materials, bio-composites such as mycelium present significant uncertainty. The use of some building materials, such as hemp and timber might also increase fire risk.	The impact of this challenge is on pricing risks involved in professional indemnity insurance and building defects insurance. This is likely to increase the costs of providing insurance. Active collaboration with industry to acquire data on building materials would enable better insurance products.
New supply chains	The trend towards offsite construction can simplify supply chains, reducing the risks involved for main contractors, though entry by more specialised, smaller suppliers could increase chain risks.	Supply chain insurance and contractors all risks insurance can be adjusted to protect contractors against new supply chain risks, if they are priced appropriately.
Building regulations and certifications	Liability risks over failing to meet building regulations or certification standards are set to increase. Should there be explicit requirements on embodied carbon and life cycle assessments, there will be appetite for appropriate insurance.	D&O insurance against litigation for failure to disclose embodied carbon accurately.

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